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ENGINEERING

FACTS AND FIGURES FOR 1867.

AN

ANNUAL REGISTER

OF PROGRESS IN

MECHANICAL ENGINEERING AND CONSTRUCTION.

WITH NOTES ON THE

VARIOUS DEPARTMENTS OF THE PARIS EXHIBITION 1867.

ILLUSTRATED BY NUMEROUS PLATES AND WOODCUTS.

LONDON AND EDINBURGH:
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PREFACE.

APR 10 1922
D. EX.

A CONSIDERABLE portion of this the fifth volume of Engineering Facts and Figures, which is now presented to the Reader, is taken up with notices of several of the Departments of the Paris Exhibition of 1867—the great event of the year—of which its pages are a record. Much of the matter in connection with this great gathering of the materials and objects connected with the Arts and Sciences, has been specially prepared for the pages of this work; while much also has been culled from Journals which are named below. In addition to this special feature of the present volume, the features which have distinguished preceding volumes have also in great measure been attended to and secured. These have, however, in consequence of the length to which the Paris Exhibition matter has extended, been considerably contracted; and are, indeed, mainly confined to abstracts or reproductions of the leading papers of the year read before the various societies, and a few of the most valuable and suggestive papers of the leading Journals.

In preparing the volume, the Editor has to acknowledge

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his indebtedness for some of its matter to the following periodicals:—'Engineering;' 'The Engineer;' 'The Mechanics' Magazine;' 'The English Mechanic;' 'The Practical Mechanics' Journal;' 'The Civil Engineer and Architects' Journal;' 'The Scientific Review;' 'The Journal of the Society of Arts;' and 'The Scientific American.' To these, as well as to 'The Building News' and the 'Builder,' the reader is referred for various important papers, space for even the briefest of epitomes of which could not be had in the present volume.

CONTENTS.

DIVISION FIRST.

Page

Boilers, &c.,—

Remarks on Boiler Construction and Boiler Explosions, . 1
Boilers at the Paris Universal Exposition of 1867, . . 6
Howard's Boiler, ... 7
Galloway's Boiler, ... 16
Hayward, Taylor & Co.'s Boiler, ... 19
Foreign Boilers at the Paris Exhibition, ... 19
The Field Patent Safety Boiler, ... 21
The Harrison or Cast Iron Sphere Boiler, . . . 25
Martin's Boiler, ... 35
Tubulous as compared with Cornish Boilers, . . . 39
Leslie's Gas Burning and Superheating Boiler, . . . 41
Marine Boilers, ... 42
Welded Boiler Joints, ... 50
Boiler-making, ... 52
Boiler-setting, ... 57
Principles involved in the Designing of Vessels for Generation of Steam, ... 58
Novel Invention to Prevent Incrustation of Boilers, . . 68
Safety-valves, ... 77
Steam Gauges, ... 92
Some Boiler Appliances as shown at the Paris Exhibition of 1867, 96
Points of the Boiler at which to supply Water, . . . 103
Priming Preventer, ... 104
Boiler Explosions, ... 105
Injury of Furnace Crowns, ... 105
Notes from the Annual Report of the Midland Boiler Association, 112

Page
Explosions from Overheating Boilers, ... 149
Overheated Steam Boilers, ... 152
Boiler Explosions not always mysterious, . . . 158
Corrosion of Steam Boilers, ... 160
A New and Simple Preventive of Explosions, . . . 161

DIVISION SECOND.

Fuel and Furnaces,—

Artificial Fuel at the Paris Exhibition. 163
Effect of Exposure on Coal, ... 167
Monmouthshire Steam Coals, ... 170
Peat Fuel—Origin and Composition of Peat, . . . 171
Manufacture and Combustion of Peat, ... 173
Petroleum and its Uses as a Steam-Generating Fuel, . . 176
What is Petroleum ? 176
Petroleum for Steamers, ... 178
The Petroleum Trial, ... 179
Petroleum as Fuel of Locomotives, ... 181
Pulverization of Liquid Fuel, ... 182
Liquid Fuel in Combination with Steam for Steam-generating Purposes, ... 183
Gas as a Steam Generator, ... 189
Gas-heated Boilers, ... 192
Water and its Effects on Steam Boilers, ... 193
New Smoke-consuming Apparatus, ... 205
Smokeless Furnace, ... 207
The Consumption of Smoke in the Potteries, . . . 207
The mechanical Equivalent of heat, ... 208

DIVISION THIRD.

Steam Engines,—

Steam Engines at the Paris Exhibition of 1867, . . . 215
Hick's Engine, ... 215
The Allan-Porter Engine, ... 216
Andrews' Oscillating Engine, ... 221
Thomson's Rotatory Engine, ... 224
Special Features of French Engines, ... 226

Page
The Corliss Engine, ... 233
Steam Engines for Winding and Pumping, . . . 235
Pumping Engines for Town Water Supply, . . . 237
Hints for Inventors on Steam Condensors, . . . 245
Counterbalancing Reciprocating Engines, . . . 250
The Practical Advantages of Superheating Steam, . . 258
Expansion of Steam, ... 261
Rotary Steam Engines, ... 264
Locomotive Engines at the Paris Exhibition, . . . 270
Austrian Locomotives, ... 272
A Noted London Locomotive, ... 273
Four-Cylinder Locomotive, ... 274
Another Remarkable Engine, ... 275
Adjustment of Counterweights, ... 276
Reversing Screw, ... 277
French Marine Engines, ... 278
On the Three-Cylindered French Marine Engine, Paris Exhibition, 282

DIVISION FOURTH.

Prime Movers other than Steam Engines,—

Shaw's Hot-Air Engine at the Paris Exhibition, . . . 287
Otto and Langen's Gas-Engine at the Paris Exhibition, . . 289

DIVISION FIFTH.

Tools,—

Machine Tools in the Exhibition, ... 292
American Machine Tools, ... 292
Other English Tools, ... 297
Whitworth's Machinery, ... 298
Foreign Machine Tools, ... 299
Belgian Tools, ... 299
Prussian Tools, ... 302
North German Tools, ... 303
Swiss Tools, ... 304

DIVISION SIXTH.

Mechanical Appliances,—

The Care of Belts, ... 305

Page
Handles—their Variety and Adaptability, . . . 306
Friction Wheels for Driving Machinery, ... 308
Mechanical Paradox, ... 309
Lock Nuts not Understood, ... 311

DIVISION SEVENTH.

Metals,—

Metals at the Paris Exhibition, ... 312
Cast Steel at the Exhibition, ... 312
On Iron and Steel at the Exhibition, ... 319, 326
New Modes of making Steel, ... 328
Cleveland Iron at the Paris Exhibition, ... 332
Castings at the Paris Exhibition, ... 335

DIVISION EIGHTH.

Railways,—

Railway Carriages, ... 337
An American View of the Rolling Stock of English Railways, . 350

DIVISION NINTH.

Marine Engineering,—

Types of Ships in the French Navy, ... 355
Admiral Halsted's Ships of War, ... 359
On a New System of Hydraulic Propulsion, . . . 361

DIVISION TENTH.

Agricultural Machinery in the Paris Exhibition, . . 364

ENGINEERING
FACTS AND FIGURES FOR 1867.

DIVISION FIRST.

BOILERS AND VESSELS FOR CONTAINING STEAM AND OTHER FLUIDS UNDER PRESSURE.

1. TAKING as true, the aphorism of an eminently scientific writer on mechanical subjects, that "all boilers should be so constructed that their explosions may not be dangerous,"—the result of the past year's experience would seem to prove, and that very decidedly, that boiler construction has gone back in place of having made progress; so numerous were the explosions which took place during it, and so dangerous to life and property were their results. Although, however, it would not be safe to draw this very definite conclusion from the past year's experience, still the condition of matters which it discloses is quite unsatisfactory, and is not that which gives us the assurance that we are making rapid progress in the direction of *safe* boiler construction. So far from rapid indeed, that able authorities do not hesitate to say that before it can be rapid an impetus will have to be given to it in a direction quite different from any hitherto at work. This impetus referred to is that obtainable by a system of legislative supervision. To many it may appear a dangerous thing to invoke the aid of a system of interference which would in many of its aspects be cumbersome and troublesome, while it would, to a certain extent, be an interference with individual action; still, in view of the great loss of life and property

which annually results from defective boiler construction, and in view moreover of the truth, that it is the duty of society to provide for the safety of those who cannot provide it for themselves; and, further, to control the action of those who are indifferent as to any loss which may result from that action; it would seem to be the wisest course before us to take up and carry out a system of legislative supervision similar to that employed in the inspection of steam ships, of mines, and of factories. Failing this mode of dealing with the subject, a mode which it is right to say is gravely objected to by many who have a claim to be heard upon it, it is satisfactory to know that those Associations which have of late years been brought into operation for the inspection and assurance of boilers are progressing favourably. Take, for instance, the last issued Report of the "Boiler Insurance and Steam Power Company," of which we give an abstract from the "Mechanics' Magazine," and from this we find very satisfactory evidence of the truth of this. "The ordinary inspections made by the officers of the Company in 1865 were 25,519; in 1866, 25,990; showing an increase of 471. Boilers examined internally in 1865, 698; in 1866, 708; showing an increase of 10. Boilers examined thoroughly in 1865, 2,608; in 1866, 3,175; showing an increase of 567. Total examinations in 1865, 28,825; in 1866, 29,873; showing an increase of 1,048. In addition to the boilers inspected, 527 engines have been inspected and indicated. The principal defects reported are as follows:—Fractures of plates and angle-iron, 499; corrosion of plates and angle-iron, 854; safety valves out of order or overloaded, 554; pressure gauges out of order, 380; water gauges out of order, 304; boilers injured in consequence of deficiency of water, 79; boilers injured from overheating, in consequence of accumulation of deposit, 17. From one or other of these defects many of the boilers inspected were found in a very dangerous condition, and but for their timely detection it is probable that the already long list of explosions would have been still further increased.

Mr. Longridge observes that boiler explosions have been more numerous and more fatal than in the preceding year. The following list gives those which have come under his notice, but probably does not include all that have taken place:—

	Boilers.	Lives lost.
Mines,	12	13
Iron and Engineering Works,	11	12
Marine,	8	12
Locomotive,	6	2
Saw-mills,	3	2
Paper-mills,	4	1
Corn-mills,	2	0
Flax-mills,	2	0
Cotton-mill,	1	4
Agricultural Engines,	2	3
Portable Engines,	3	10
Docks,	2	2
Brewery and Distillery,	2	2
Rag Works,	1	2
Manure Works,	1	7
Chemical Works,	1	2
Webbing Factory,	1	1
Miscellaneous,	13	12
Total,	75	87

It will be seen that mines and ironworks still retain their place at the head of the list, as in previous years, but of late several of the owners of such works who formerly were opposed to inspection, deeming their own men quite competent for the task, have changed their views, and given proposals for insurance. Mr. Longridge's elaborate report is illustrated by photographs of portions of exploded boilers, and also of the scenes of boiler explosions, from which we may realise to some extent the fearful havoc such a catastrophe brings with it.

Since the beginning of the year 1859, when the Boiler Insurance Company was formed, not less than 397 boiler explosions have been recorded in Great Britain, causing the loss of 641 lives. During the same period more than 15,000 boilers have been inspected by the officers of the company; and of those insured only twelve have exploded, viz., six plain cylindrical boilers, and six with internal furnaces. Although, for the reasons given in the report, the system of inspection which has been adopted may not have been so perfect as is desirable, or as we may yet hope to see it, it cannot but be admitted that it has been productive of much good, not only by the timely detection of defects which would otherwise, in all probability, have resulted in explosion, but also by inducing greater care and economy in the use of steam power. The success which has attended the operations of the Company to the present time may be accepted as a proof that it has been established on sound principles, and gives good ground for anticipating increased progress and prosperity in future years." While noticing from the above, what at the beginning of our remarks we pointedly alluded to, that the number of explosions during last year had been greater than usual; it should however be remembered that the makers of boilers are not always to be blamed for so sad a result; much blame attaches itself to the users of them. On the position respectively occupied by the maker and the user, the "Mechanics' Magazine" has the following, in referring to a very disastrous explosion of an agricultural engine.

"If any apology is necessary for our frequent recurrence to the subject of steam boiler explosions it is assuredly to be found in the frequency of the explosions themselves as well as in the carelessness, or rather culpable negligence, of some makers and some attendants. In the present instance we have both of these parties promoting a catastrophe by which eight lives were sacrificed and four persons were injured. The boiler belonged to an engine of the agricultural class, and the fact that too little attention is paid to the fitting as well as to the working of these engines induces us once more to raise a protest against such a condition of things as these boiler explosions too frequently disclose. The explosion occurred in March last at a farmstead, the boiler being of the portable multitubular agricultural type, and employed for driving threshing machines. On exploding it was rent into two main fragments, the fire-box with the flue tubes being separated from the barrel of the boiler, while in addition the plate forming the sides and top of the outer casing of the fire-box was ripped off. These fragments were scattered right and left, one of them being thrown across the road into an adjoining field, to a distance of 40 or 50 yards. Unfortunately, the explosion occurred at dinner-time, when the workpeople had clustered round the boiler for the warmth it afforded them on a cold day with a biting east wind, the result being that eight of them were fatally injured, and four more were wounded. From the report of Mr. Fletcher, the engineer, to the Manchester Boiler Association, the cause of the explosion seems to have been of the simplest kind. The engine-driver was seen shortly before the explosion to be working the boiler with the safety-valve lever tied down by a cord, so that as soon as the engine was stopped for the dinner hour, the boiler burst from accumulated pressure. The engine-driver was amongst those killed, and there can be no doubt of his suicidal negligence. It should, nevertheless, be pointed out that the complement of fittings with which the boiler was equipped was very inefficient, and had it been as complete as it ought to have been, there is every ground to conclude that the explosion would have been prevented and the lives saved.

We thus see that the maker is to some extent responsible for the result, for in the case of farm engines, the users and much less the attendants can hardly be supposed to discriminate between well and ill-appointed boilers. The boiler in question had no pressure gauge or duplicate safety-valve. Had there been a steam gauge it would have indicated the excessive pressure, and had there been a duplicate safety-valve of suitable construction, the attendant could not have gagged it simply by a cord. We do not pretend that any safety-valve is proof against the attacks of skilled malice, for anything that can be made by one man can be deranged by another. But the safety-valves on portable engines are simply exposed to the negligence and stupidity of ignorant men, and there are valves which would to a very great extent meet the case. At any rate, the best appliances should have a fair trial, and portable engines ought no longer to be allowed to work thus inefficiently equipped. A careless man may make them as dangerous as a powder magazine simply by tying down the safety-valve lever, or by giving an extra turn to the thumbscrew on the spring balance. From the fact of portable engines being left to farm labourers to tend, the fittings should be all the more efficient and less liable to derangement. Instead of this they are, as a rule, far inferior to those adopted in the general run of stationary boilers, although these are intrusted to skilled labour. In the name of common humanity we protest against the persistent neglect of due precaution on the part of those who make and those who work these portable boilers and engines. If they must be badly tended, in common honesty let the makers give ignorance a chance for life by properly mounting them." While, however, fairly apportioning to the maker and the user the blame of any accident in which both can be proved to be at fault, it should not be overlooked that the party, as a general rule, principally to blame is the maker of the boiler. For, as we have more than once pointed out, that the users of boilers may plead as an excuse for having neglected a precaution, or indeed brought about a defect, that they were profoundly ignorant of the effects of the one or the other; they at the same time depended upon the professional experience of the maker, employing him indeed upon the very assumption that he possessed that experience. All this points to what able men have for long time advocated as a prime necessity in the relationship of maker and user; that the maker should be competent to undertake and to give good—nay, the best of work—and have moreover so high a morale as to be above the temptation to do bad work simply because for the occasion it may pay best. In this, as on other subjects of importance, much good may be done by the exposition of the views of sound and able authorities, able to take enlarged and accurate views of all the points connected with it. It is in the doing of a practical good like this, that our various Journals devoted to the exposition of mechanical and scientific subjects are so valuable; and in a similar, if less powerful and marked direction, a work such as that we have now the privilege again to present to our readers. The matter bearing upon the most important Division, which takes up the subject of Boilers, will be discussed under three Sections:—FIRST, *The Form, Materials, and Construction of Boilers*; SECOND, *Boiler Appliances and Management;—and* THIRD, *Boiler Explosions.*

SECTION FIRST.—THE FORM, MATERIALS, AND CONSTRUCTION OF BOILERS.

2. *Boilers at the Paris Universal Exposition of* 1867.—In the vast collection of machinery which was to be met with at the Great International Exposition held at Paris in 1867, there was no department so full of interest to the Engineer as that which comprised prime movers, steam boilers, and apparatus and appliances connected therewith. The examples were not only numerous, but the great majority of them were characterized by excellence of construction, and in some cases by novelty of ar-

rangement or of principle. We purpose in this, and in the next three divisions, to draw attention to steam generating apparatus and the appliances used in connection with these, and thereafter to the steam engines and other prime movers,—the present paragraphs being devoted to steam boilers. In the boiler house attached to the British department of the machine gallery in which the boilers were placed by which the steam was raised for the supply of the machinery in motion, there were three examples of boilers, (*a*) Howard's, (*b*) Galloway's, and (*c*) Hayward Taylor and Co's.

(*a*) *Howard's Boiler.*—The following description of this boiler is taken from the most important paper read during the

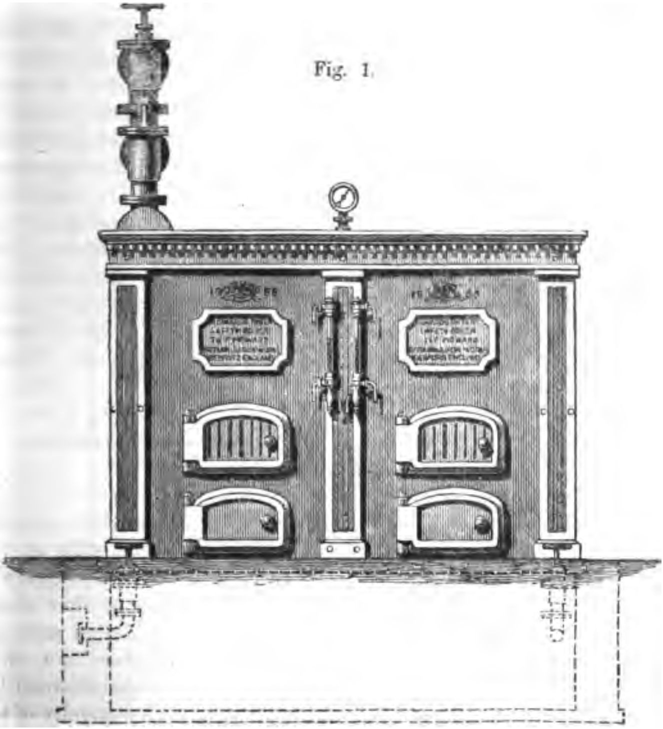
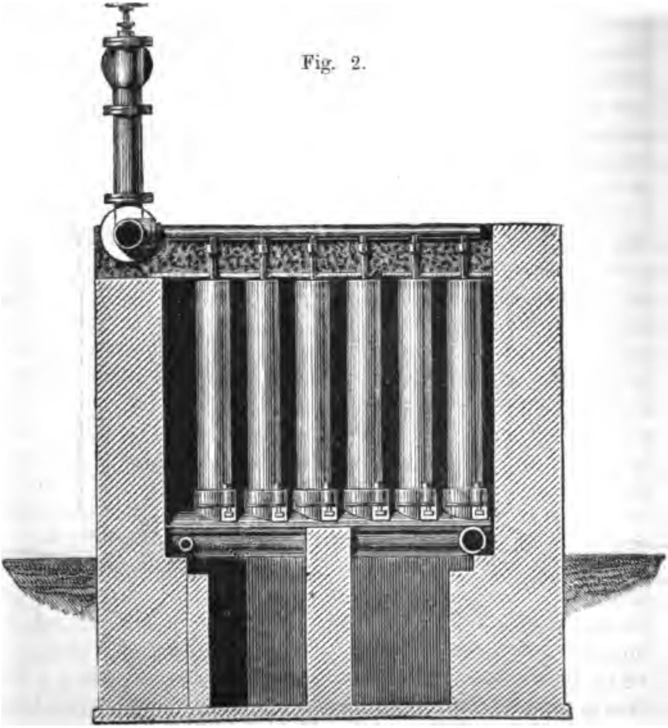


Fig. 1.

year, being that by Mr. Vaughan Prendred, C. E., before the Society of Engineers on "Water Tube Boilers." Mr. Howard's boiler is illustrated in figs. 1 to 4 inclusive, and in figs. 1, 2, Plate I.; fig. 1, being a front elevation; fig. 2, a cross section; fig. 3, part longitudinal section; and fig. 4, part plan. In Plate I. enlarged views of the tubes are given. The inventor is Mr. James Howard, of the well-known firm of James and Frederick Howard, Britannia Works, Bedford. "Before proceeding with its description, it may be well to premise that Mr. Howard draws his supply of feed water from the river Ouse, on the banks of which the Britannia Works are situated. This water is excessively muddy at certain seasons, and at all times it throws down

Fig. 2.



a great deal of deposit. The machinery of the Britannia Works is driven by a high and low pressure double-cylinder double-beam engine by Goodfellow, and formerly supplied with steam by a pair of boilers constructed on a principle patented by him. These boilers were of the Cornish type, with an internal flue disposed centrally in the shell, and not nearer to the bottom than the top, as in the ordinary Cornish boiler, the object being to avoid the effects on the ends of unequal contraction and expansion. In consequence of the bad quality of the feed water, these boilers were an endless source of trouble ; they were always leaking and being repaired. The author examined them a few weeks since on Mr. Howard's wharf, and found them patched in many places, and comparatively worn out, although only a very few years in use. Mr. Howard then cast about for something better. His attention was called to a form of tubulous boiler well known, and he conceived the possibility of producing one for himself. That about to be described is the result of the labour and experiment of more than twelve months, and at this moment the engines at the Britannia Works are driven by three boilers nearly similar to that shown by the model on the table.

"Each boiler consists of a series of vertical tubes 4 ft. 6 in. long and 7 in. in diameter, of wrought-iron, welded, and closed at the upper end by flat plates less than half an inch thick welded in. Round the lower ends of these tubes a heavy ring of cast-iron with two projecting lugs is fixed, on a system largely employed in other ways by Mr. Howard. The tube is roughened at the lower end for a length of about 4 in., it is then placed in a mould and the metal cast about it. There results so perfect a union, owing to the contraction, and possibly to a certain amount of welding action, that the tube and the pipe are virtually rendered one. The author has seen a force of 77,000 lb., or more than thirty-four tons, applied to draw off one of these rings without producing the slightest symptom of giving way.

"The tubes are disposed, as will be seen, in transverse rows in a flue or oven, as it may be termed, intervening between the furnace proper and the chimney. The lower ends of all the tubes in a transverse row are united by a cast-iron tube about 10 in. in diameter outside, and of considerable thickness. This tube is further strengthened by transverse perforated parti

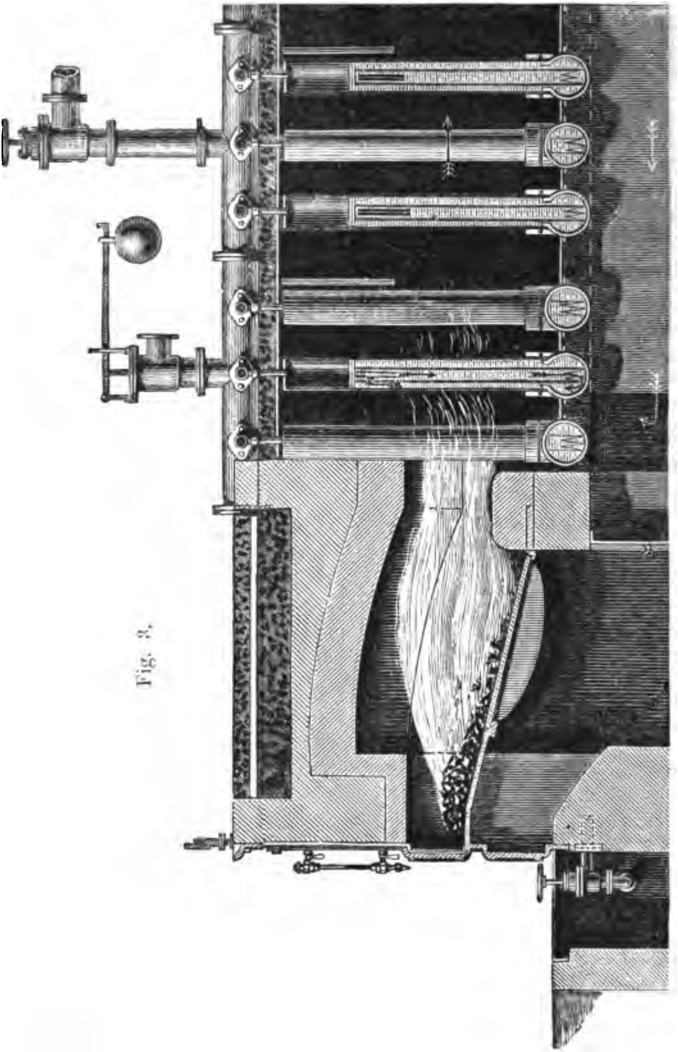


Fig. 3.

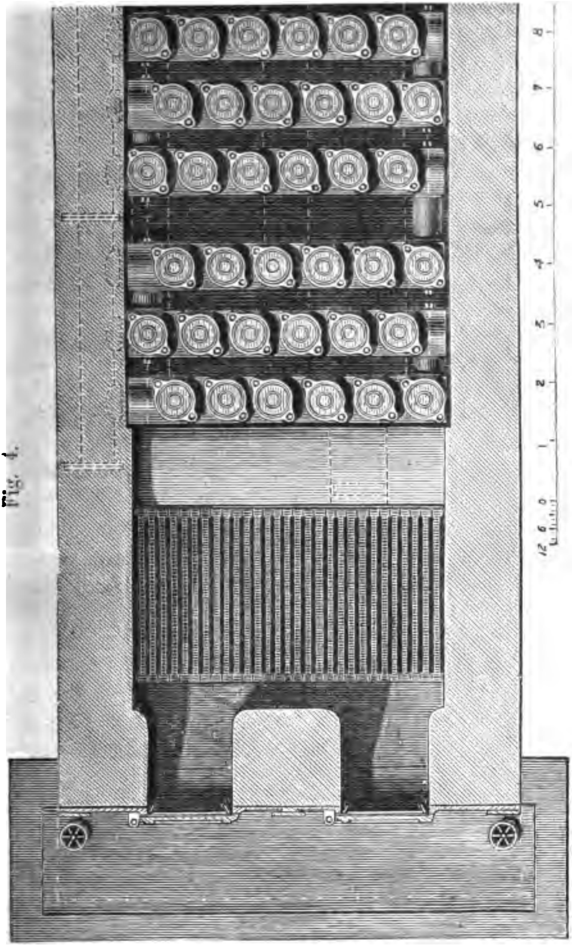


Fig. 4.

seen very clearly in the enlarged model. The vertical tubes are united to this in a way which will be better comprehended from the drawings and models than from any written descriptic will be seen that on the upper side of each cast-iron tube flat pieces, or pedestals, if we may use the word, are cast. In each of these is turned an annular groove as wide as the end of the vertical tube is thick, say ⅜ in., and of considerable depth. The ends of the vertical tubes project slightly beyond their cast-iron base rings, and this projection fits into the circular channel before referred to. The end of the tube is turned off fair in the lathe.

"In two opposite corners of the squares or pedestals on the cast-iron tube recesses are made, and into each of these is slipped a heavy gun-metal tapped nut. These nuts can be drawn out or put in laterally, but they are held down by the cast-iron of the pedestal which overhangs them on three sides. The base rings of the vertical tubes have lugs cast on them, which, when the tube is put in place, correspond with the gun-metal nuts to which they and the tube with them are secured by two bolts, one at each side, screw into the nuts. Before the tube is put in place, a ring of composition, made of lead and tin, is dropped into the annular groove, and on this the end of the tube rests, and being forced down by the two bolts at opposite sides makes a joint tight at any pressure which the tubes can sustain, and yet one which may be made and broken ten times in the day if necessary.

"Turning now to the upper ends of the tubes, it will be seen that a short piece of welded gas-pipe rises from each. This pipe serves to carry off the steam to the main steam pipe. Between every double row of generating tubes one steam pipe is fixed horizontally, and the short tubes are bent over by an easy curve and screwed on to the sides of these secondary steam pipes, as they may be termed. All the secondary pipes open into one large pipe running at right angles to them. On this is fixed the safety-valve, and to a flange at one end the steam pipe to the engine, or where more boilers than one are used, a branch of that pipe is fixed. The effect of this arrangement is that the generating tubes are only secured at one end, and can therefore expand or contract as they like without imposing any strain on any part of the boiler. The steam pipes are also free to move as they wish, the curve in the small pipes from the generating tube providing sufficient elasticity to meet any demands which are likely to be made on them. The cast-iron bottom mains can expand or contract as they please, and in any direction. In one word, the entire boiler constitutes a flexible system, the relative position of the various separate members of which may alter through comparatively wide limits without setting up any injurious strain, and this the author considers an essential feature in any boiler which claims to be thoroughly good; nor is he aware that in any other boiler in use, taken as a whole, is the principle of providing means to minimise the strains due to expansion and contraction so fully developed.

"It would be assumed at first sight that the generating tubes in Mr. Howard's boiler are so long in proportion to their diameter that the violent ebullition going on within them must render special means of giving circulation absolutely indispensable, yet this is not the case, as a boiler without any expedient of the kind has given very fair results. In order, however, to provide that rapid circulation which is required to sweep off the clinging layers of steam, which, unless removed, would prevent the absorption of heat from the sides of vertical generating tubes, Mr. Howard resorts to a very old expedient, first used, the author believes, by James. Within each vertical generator is placed a tube of galvanized iron. In his first experiment, this tube was cut off transversely a little below the water-line, the bottom rested on the bottom of the cast-iron transverse main and was vandyked to provide the water free access. The water ascended in the annular space between the tubes, and descended within the inner pipe in a way too well understood to need explanation. After a boiler so fitted had been at work some time it was found that the generating tubes, although free from deposit at the lower end, carried a good deal at the top in the form of a cone. This showed some peculiarity of action in the currents, and the inventor then adopted a tube rising above the water-level and going right to the bottom—slots cut in the sides near the top providing for the downward return of the water, no matter what the level. With this the results have been highly satisfactory, the circulation being so violent that the sediment is not allowed to adhere, and the boilers being blown out from time to time, no further trouble is experienced at the Britannia Works from deposit. The manner in which the feed-water is introd will be easily comprehended. Each transverse main has its own supply pipe.

"We have next to consider the method in which this boiler is heated. The furnace, it will be seen, consists first of the fire-chamber proper, which contains the grate, covered by a heavy brick arch. In front of this is the tube chamber, answering very much to the hearth of a puddling furnace, and under this last the flues are returned before going to the chimney. It is one of the distinguishing principles of this boiler that no joint of any kind is exposed to the action of the fire or heated products of combustion, at least while they retain a temperature much above that of the steam within the boiler. In order to carry out this object the tiers of vertical tubes are set as follows:—The transverse cast-iron mains rest on side walls, and a central wall which establishes a wheel draught, the mains are fixed rather closely together, and as soon as they are put in place cast-iron plates are laid between them or flanges or ribs cast on the sides of the mains for the purpose; on these are laid bricks and fire-clay to such a height as to cover the junctions of the tubes with the mains effectually; the lower half of the mains project into the under flues and absorb the last dregs of heat from the gases on their flight to the chimney. On the upper ends of the tubes wrought or cast-iron plates are also laid, and these are covered with six or eight inches of sand to keep in the heat. By taking off the sand and removing a couple of plates access may always be had to the interior of the tube chamber. It will be remarked that the whole tube, steam space and all, being exposed to the heat, its upper portion would be liable to rapid destruction. To prevent this a provision apparently insignificant, but really very important, is introduced, in the shape of certain screens of fire-clay, which extend across the tube chamber and protect the upper portions of the tubes from the impact of the flame. The manner in which the flame acts is so clearly shown in the drawing that the author feels it would be but wasting time to enlarge upon the subject now. It remains to be seen what are the practical results which have been obtained with this boiler. The author is indebted to Mr. Howard for the following particulars on this very important subject:—In the first experiment one boiler was used to drive the engine, instead of one of the old boilers already referred to, which had been removed. It was at once perceived that there was a saving effected in fuel. A tank was then constructed, and from this the water was forced into the boiler by an injector. The result showed a very fair evaporative efficiency. The inventor then called in a competent engineer, and placed both the boilers in his hands to carry out an impartial experiment. The power of the engine was taken with a friction brake, and many trials were made, of which the following may be accepted as a fair sample:—

"Cornish boiler, by Goodfellow: Duration of experiment 2 h. 57 m.; coal used, 11 cwt. 2 qrs.; water evaporated, 520 gallons, say 5,200 lb. = 4·03 lb. of water per pound of cobble coal.

"Howard's boiler: Duration of experiment, 4 h. 24 m.; consumption of fuel, 10 cwt. 2 qrs.; water evaporated, 750 gallons, or 7,500 lb. = very nearly 6·4 lb. of water per cwt. of cobble coal. An experiment was then tried as to the time required to raise the steam in each from cold water. The result was that the Cornish boiler used 7 cwt. of coal, and occupied 1 h. 40 m.; the water-tube boiler 2 cwt. of coal and 20 m.

This was deemed so satisfactory that Mr. Howard at once proceeded with the construction of two other boilers, into which he introduced certain improvements, and succeeded in reducing the temperature of the products of combustion from 550° or 600°, that measured near the base of the chimney when the Cornish boiler was at work, to 400°, that measured by the author at the end of the tube-chamber. The pressure of steam was 90 lb., the temperature proper to which is 331°. The difference, therefore, between that of the water in the boiler and of the gases was but 69°. The third boiler has been still further improved by arranging the rows of vertical tubes so that they no longer run in lines, but break joint, as it were. Mr. Howard informs the author that in recent experiments it was found that 36 seven-inch tubes arranged thus were as efficient as 81 five-inch tubes arranged in parallel rows, a fact which strongly corroborates Peclet's views already explained, the surface being as 756 is to 1215.

The author will not occupy time by considering further the results of the important trial with the Cornish and water-tube boilers. It will constitute a good subject for discussion, but he wishes it to be understood that the water-tube boiler tested was the first of the kind ever constructed, and that it was hastily put to work before the mortar was dry. The evaporative efficiency, again, of both the boilers tested is so very low that the coal (Derbyshire) must be of inferior quality. As the matter stands, the water-tube boiler proved in impartial hands 50 per cent. better than a Cornish boiler by a first-rate maker, and in no respect differing in set or design from that of hundreds of other boilers in use in the manufacturing districts."

(*b*) *Galloway's Boiler.*—The following description of this form of boiler is also taken from the paper of Mr. Prendred:—

"Messrs. Galloway's boiler may be described as an ordinary Cornish boiler, into and across the central flue of which conical tubes are fixed, these tubes opening into the water space at each end. As first and still made, the flue was a flat oval, and consequently a greater depth of water could be carried over the top than is admissable with the circular flue. The tubes acted so effectually as stays that such a boiler as that put up at the Gutta-percha Works in the City-road seventeen or eighteen years ago are as strong with main flues 4½ ft. by about 3 ft. as any boilers could be. The late Mr. Robert Armstrong, speaking of these boilers, in his admirable little treatise on boilers published in Weale's series, states that when working moderately the evaporation of one boiler was found to be very accurately one cubic foot of water per minute, and the consumption of coal was 336 lb. per hour, equivalent to rather more than 11 lb. of water evaporated per pound of coal in regular work. It is to be regretted that Mr. Armstrong did not supply full particulars of the experiment, as the result is abnormally good. The advantages of the Galloway tubes soon came to be recognised, and applications were made to the makers to fit them to the ordinary circular-flued Cornish boiler. This is very easily done by making the taper of the tubes such that the flange at the lower end will pass through the hole made near the top of the flue. In some cases, the whole flue is taken out and fitted with Galloway's tubes, in others the tubes are put in without removing the flue; the rivetting being easily effected when the tubes are placed diagonally instead of vertically. Messrs. Galloway are now fitting these tubes all over the kingdom, and the author has not in a single instance heard that they did not give perfect satisfaction. He may add that Messrs. Galloway inform him that they have now over 30,000 tubes at work, a fact which speaks well for their popularity. It will be seen in a moment that the heating surface of the Galloway tube is disposed in the best possible way. Not only do the tubes break up the current of flame and receive its impact to the best advantage, but they secure that precise description of circulation which the author has proposed, and he trusts proved, to be the best. The water moves along the tube, continually rising and moving away from the heating surface. All engineers are agreed as to the value of overhanging surface as compared with vertical surface; the first being the best because it tends to prevent the clinging of a film of steam to the metal, and in those tubes we have the overhanging surface; and in this respect, but in this alone, the Galloway tubes are better disposed than those of Mr. Howard's boiler, which last would, however, be brought on a perfect equality by making the tubes taper upwards, say 5 in. diameter at the bottom and 8 in. at the top, or more simply, and probably with as good effect, by inclining the tubes from the vertical toward the furnace.

Galloway's boiler is inferior to a true tubulous boiler, because it possesses a shell and contains a very large quantity of heated water, part of which would be converted into steam in case of rupture, and cause a violent explosion. But it is no worse, as regards this point, than the boilers now generally used throughout the world, and it is immeasurably superior to the Cornish boiler in more than one respect. The Galloway tubes act so efficiently as stays that no fear of a collapse of a flue need be entertained. The flue is rendered by their presence very much the strongest part of the whole boiler. Besides this, they promote circulation and save the boiler many of those strains which always, when allowed to operate unchecked, terminate sooner or later in the destruction of both shell and flue by the deterioration of the iron, caused by the bending and buckling of the plates and seams. The tubes, by promoting circulation, prevent the existence of a marked difference between the temperatures in various portions of the generator. In the Cornish boiler it is no uncommon thing to find cold water under the flue on Monday morning, after the steam has been up some time; the mixture of the water above the flue with that below depending a good deal on the currents caused by the entrance of feed-water. But in the Galloway tubes the water is rapidly evaporated and displaced by the rising steam, and as it rushes in from below currents are set up throughout the whole mass, which render an inequality of temperature an impossibility.

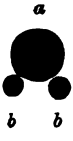
The boilers illustrated have been supplied to the order of the British Executive Committee of the Paris Exhibition. They do not require particular description. It will suffice, in the author's opinion, to state that they are 24 ft. long by 6 ft. 6 in. in diameter, and are each equal to 46 horse power. Experience has demonstrated that each of these boilers will generate as much steam as a double-flued Cornish boiler 28 ft. by 7 ft. In every respect the Galloway boiler is, in the author's opinion, the best large-shelled boiler in use; but, as he has before stated, he considers all such boilers inferior to the true tubulous boiler, such as Alban's or Howard's, principally because they are far more liable to dangerous explosions; and it should always be the aim of the engineer to produce a boiler the explosion of which shall not be dangerous."

In "Engineering," May 25th, 1867, drawings and description of the boilers erected by Messrs. Galloway at the Paris Exhibition of 1867 were given, from which we have prepared the following, illustrated in Plate II., fig. 1. These boilers were nominally of forty-five horse power, but could raise steam for engines giving out four times that indicated power. The length of each boiler was 24 feet; diameter, 6 feet 6 inches; the outer shell of each being made of the best Shropshire plates, ⅜ths of an inch thick, the end plates being ⅞ths thick, the ends being secured to the barrel or outer shell by gussets and double angle irons, spaces of nine inches being left between the gussets and the flues to admit of the proper adjustment of the end plates around the flues, which are subjected to unequal expansion and contraction. The longitudinal joints of the barrel or outer shell are double, the transverse seams single riveted. The boilers are double furnaced, the length of each furnace being 6 feet 6 inches, the diameter 2 feet 8 inches; these two furnaces unite or join into a single flue, elliptical in section, the transverse diameter being 2 feet 9 inches, the conjugate 5 feet; the fire-grate is made of three lengths of bars, each 1 foot 10 inches long, $\frac{5}{8}$ths thick, and with air spaces between of $\frac{3}{8}$ths. The conical tubes above described are placed in the back elliptical flue, are twenty-one in number; "pockets" or projecting parts, are also provided at the points where there are no tubes, the object of these pockets being to prevent the flame and heated air running directly along the sides of the main flue, and to throw them into the centre of it, so that they will come as much as possible in contact with the tubes there placed. The heated air is passed from the main or central flue, along a flue at each side of the barrel or outer shell of the boiler, then along a central flue under the boiler to the chimney flue. The boilers are supported on blocks of fire-clay. The side flues are 4 feet 3 inches high, the upper roof of which is on a level with the inside boiler flues, the width of the under flue being 3 feet 3 inches, and height at centre of boiler 2 feet. The steam is taken from each boiler by a steam chamber, 2 feet in diameter and 6 feet long, the steam being taken to the engine from this chamber by a pipe. Each boiler is provided with two safety-valves, and the ordinary pressure of working was 50 lbs. In fig. 2, Plate II., we show the application of Galloway's water-tubes to a single, and in fig. 3, to a double fluid Cornish boiler.

(*c*) *Hayward Taylor and Co.'s Boiler.*—The reader will find a description of this boiler, the patented invention of Mr. Jordan, in the vol. for 1866 of "Engineering Facts and Figures," p. 7, par. 3, fig. 2.

3. *Foreign Boilers at the Paris Exhibition of* 1867.—We give a place to a description and illustration of a few of the boilers of Foreign Exhibitors in the present par., the limits of which we regret precludes the possibility of noticing all of the exhibits in this department. These, indeed, were so numerous that a large portion of the volume might easily enough be filled with matter relating to them. In figs. 1 and 2, Plate III., we give views, fig. 1 being a vertical section, and fig. 2 a plan, of a boiler by Schmaltz, exhibited in the Prussian department, and which is adapted for a vertical portable steam-engine. In this boiler a cylindrical barrel or tube *a a*, forming the outer shell, encloses an inner barrel *b b*, constituting the fire-box; both inside and outside barrels terminate at the line *f*, and are bolted

to a cast-iron frame. The furnace is of fire-brick, and is fed through the passage *g*. The fire-box *b b* is crossed by horizontal tubes *c c*, which communicate with the water-space between the inner and outer barrels, and the heated air and gases are led from the top of the barrel *b b* by flues *d d*, which pass through the water-space, and communicate with an annular flue, from one point of which the heated air and smoke pass off to the flue *e e*, being controlled by the damper, as shown. In figs. 3 and 4, Plate III. we illustrate the form of boiler exhibited by M. Lecherf in the French department, of which, in fig. 3, Plate III., we give a longitudinal, and in fig. 4 a transverse or cross section, and of which the main feature is the employment of two lower and smaller barrels *a a*, joined by tubes *b b* to an upper barrel *c c*. The lower barrels *a a* are filled with water, and are played upon externally by the flames and heated air from the furnace *e*, fig. 3, Plate III. The upper barrel *c c* is provided with tubes *d d*. In a special Annexe at the Exhibition, Messrs. Farcot & Sons, Engineers, Saint Ouen, Seine, exhibited at work boilers, the arrangement of which is shown in figs. 1 and 2, Plate IV. An upper tube or barrel *a a*, provided with steam-dome a^1, safety-valve a^2, and feed-water apparatus a^3, is connected with a lower tube or barrel *b b* by cylindrical water-tubes *c c*. The fire-box *d d* is placed in the lower barrel *b b*, and from this the flame and heated gases are conveyed by tubes *e e* to a species of short smoke-box *f* at the end. The connection of the fire-box and smoke-box to the lower barrel is such, that by withdrawing bolts, the whole of the fire-box and its accompanying tubes can be withdrawn, whenever this operation is required to be performed for the purposes of repair or cleaning. It will be observed, on inspecting fig. 2, Plate III., that behind the front fire-bars *g* there is another set *h*, but of shorter length, the fire-grate so formed by *h* being used when extra work is to be performed by the boiler. An iron casting will be observed surrounding the barrels (see fig. 1, Plate III.): this is connected by angle irons to the lower casing *b b*, so that a series of flues are formed, by which the heated air, &c., is led to the chimney flue, the entrance to which is at *i*, fig. 2, Plate III., and the draught being controlled by a damper or valve, as shown. In fig. 3, Plate IV., we give the vertical section of the boiler attached to, and forming part of, the vertical portable engine of Manlell and Wibert, exhibited in the French department, in which A is the steam-space; B the water ditto; C C reservoirs of hot water for feeding the boiler; D D D the fire-place and flues; F F doors by which the cleaning out of the boiler is effected; G G the outer casing to which the engine is fixed; H the chimney-tube. Figs. 1, 2, and 3, Plate V., illustrate Chevalier's boilers, which were used for raising steam for driving the machinery in the French department, and which are prepared from a set of drawings given in "Engineering" of July 19th, 1867. In this arrangement there are two boilers employed, as shown in plan in fig. 2. In the boiler *a a*, fig. 2, there are two furnaces, one at each end, as shown in the longitudinal section in fig. 3 at *a a*, and which are separated by a brick bridge *b*; the heated gases proceed from these furnaces *a a* by means of the bent tubes *b b*, fig. 3, Plate V., to the main flue. These tubes *b b* surround the exterior of the cylindrical barrel *c c*, which contains the fire-places *a a*, and are therefore surrounded by the water which is contained between the barrel *c c* and the outer shell or barrel *d d*. The heated gases from each fire-place *a a* circulate in the tubes surrounded by water independently of each other, and are finally returned to the main flue, shown in plan in fig. 2, Plate V. In their passage to the main flue the heated gases circulate round two lower barrels filled with water, and placed in relation to the main barrel or shell *d d*, as thus, *a* being the shell and *b b* the two lower barrels. The steam-dome or upper shell *f f*, fig. 3, Plate V., communicates with the lower *d d* by tubes *e e*, as shown. The second boiler of the arrangement, marked *b b* in fig. 2, Plate V., has only one furnace, as shown in the longitudinal section in fig. 1, Plate V.; at *a* the heated gases passing from the fire-box through the tubes *b* to the main flue, and playing upon the under water-tubes, as shown in the last type diagram, and as explained in connection with fig. 3.



4. *The Field Patent Safety Boiler.*—In the volume for 1865 of "Engineering Facts and Figures," we gave a description and illustration of this form of boiler, (see p. 2, par. 2). We here give two articles upon its more extended application to practice, from the "Mechanics' Magazine." "Of the many classes of steam generators in the construction of which an outer shell or its

equivalent are employed, there is none that more perfectly complies with the requirements of safety and thorough efficiency than does the ordinary Field boiler, now in such extensive use, and which possesses many advantages, already enumerated in the 'Mechanics' Magazine,' and not the least important of which is the great saving it effects in the amount of space occupied. Moreover, there is no limit to the extent of steam and water room which may be given, nor is there the slightest danger of explosion even in case of shortness of water. It is nevertheless an undeniable fact that much greater strength can be attained in a properly constructed boiler formed entirely of tubes than can possibly be had in a generator of which an outer shell or casing of comparatively large diameter is a component part. Hence, among many employers of steam power the first-named class of boiler would no doubt gain preference over one otherwise thoroughly efficient, effecting an enormous saving in space, but calculated only safely to withstand what are under ordinary circumstances considered high testing and working pressures. We believe it was in view of this fact that the proprietors of the Field boiler introduced the patent safety boiler, of which our present engraving represents a longitudinal vertical section in perspective, and which, as will be seen, is of the strictly 'tubulous' class.

The furnace is constructed of brickwork in the ordinary manner, a large flue or chamber being formed at the back, into and through which the heated products of combustion pass to the chimney. Across this flue or chamber are placed a number of inclined cast-iron tubes connected by flanged joints with bolts and nuts, at their higher extremities to a longitudinal cast-iron tube constituting the main steam space. A corresponding longitudinal cast-iron tube similarly connected to the lower ends of the inclined tubes, and protected by brickwork from the direct action of the products of combustion, serves as an equivalent for the water casing employed in the ordinary vertical Field boiler, and constitutes a receptacle for the collection and deposit of sediment. The under sides of the inclined cast-iron tubes have bosses cast upon them as shown, and tapering holes are bored, into which the wrought-iron Field tubes are drifted in such manner that they hang down into the flue. On the upper part of the inclined pipes are formed a number of bosses, through which holes are drilled above each of the Field tubes, and rather larger in diameter than the latter, thus affording ready means of access not only to them but likewise to other parts of the interior of the boiler. Each hole is covered with a tapering plug secured in its position by two bolts and nuts. The radiation of heat is prevented by iron plates resting on ledges above the inclined tubes, and covered with ashes. Cast-iron plates are placed across the upper and lower parts of the flue for directing the costs of the products of combustion, so that they may impinge in the most efficient manner upon the Field tubes, the circulation of the water in which, as is well known, is of the most perfect character. Thus a much larger quantity of water is evaporated within a given space than is the case in boilers of other constructions, and almost the whole of the heat generated in the furnace (with the exception of what is necessarily employed for the purpose of maintaining a sufficient draught) is utilised in the production of steam.

This boiler possesses an advantage, the importance of which can scarcely be over-estimated, in doing away with that inevitable defect of tubes fixed at both ends without effective provision for expansion and contraction—namely, leakage, the destructive effects of which are well known. The means by which this result is attained have an important effect in simplifying the construction and reducing the cost of the boiler. Although we have already referred to the very perfect circulation of the water in the 'Field' tubes, it may, nevertheless, not be out of place to remind our readers of the precise action which takes place. Upon lighting the fire, the consequent heating of the tubes immediately causes the water in them to commence circulating, every increment of heat, however trifling, added to the water contained in the annular spaces, between the inner and outer tubes, lessening its specific gravity, causing it to ascend, and cooler water to consequently descend the inner tubes to supply its place. This action goes on increasing gradually until ebullition commences, at which time the velocity of flow is increased enormously, owing to the great difference between the specific gravity of the mixed water and steam ascending in the annular spaces, and that of the solid water descending the inner tubes. Sediment is carried up by the circulation in the 'Field' tubes, and, aided in the boiler under notice, by the excellent circulation in the inclined cast-iron tubes, is thrown to the bottom of the main water tube already referred to, from whence it is blown off in the usual manner. These boilers are perfectly accessible for examination and repair, and as the different working parts are of the most simple construction, and very few in number, we are informed that these boilers can be produced ready for work at a very moderate cost, below that of other descriptions of tubulous generators, while the extremely effective character of the heating surface enables a very considerable saving to be effected in the length and weight of the boiler, and consequently also in the cost of setting.

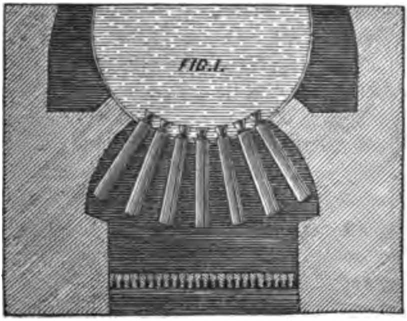
The lightness of each of the various parts, combined with their simple construction, and the ease with which they may be put together in almost any situation, are important features, which render this boiler peculiarly suitable for transportation and erection in situations where it would be impossible to employ boilers of ordinary construction. Another point in favour of the Field safety boiler is, that it can be most readily enlarged by connecting additional series of tubes in cases where it is desired to increase the effective power of the boiler. The question of tubulous boilers is now attracting considerable attention, and the conviction is steadily gaining ground that it is the true system both for economy and safety. The manifold advantages embodied in the one we have been describing point to a success which we think it cannot fail to achieve.

We have the pleasure of laying before our readers engravings showing the application of the Field tubes to ordinary Cornish and egg-ended boilers, for which they are in large demand. In the cases of Cornish boilers the tubes are applied behind the bridge, in the main flue, and although frequently fixed in plates not exceeding ⅜in. in thickness, they are invariably free from leakage, owing to the freedom of expansion and contraction attained by this system. Some few years ago, when the Field tubes were first applied to a Cornish boiler, experiments were made with a view of testing the advantages to be derived from such application. The trials were made with two boilers, both being of exactly the same size, and set in precisely the same way, and worked by the same chimney, the boilers being each 25ft. 6in.

long by 6ft. diameter, with flues of 3ft. diameter. One boiler was fitted with 36 Field tubes, the other boiler being without tubes, and the result was that in the boiler with the tubes, 5 tons of coal lasted 76 hours, and 114 tubs of water were evaporated; whereas the boiler without tubes evaporated only 102 tubs of water, and the coal did not last more than 73 hours, thus showing in all a clear gain of 15·5 per cent. in favour of the boiler with the 36 Field tubes, which were only one-fourth the number of such tubes that the boiler in question was capable of containing advantageously.

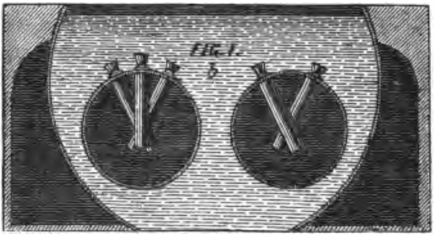
Since the foregoing experiments, many thousands of the Field tubes have been applied, and they have given great satisfaction. As a very recent instance of their success, we may mention that Mr. G. R. Cowen, the well-known boiler-maker of Nottingham, recently applied 21 Field tubes to a boiler at the establishment of Messrs. Carver and Mosley, who, before having the tubes, laboured under the greatest difficulty through not being able to make steam enough to drive their machinery; but these gentlemen state that after the application of the 21 tubes they experienced no difficulty in driving, and that a saving of 25 per cent. in fuel has been effected. So satisfied were they with the result, that Mr. Cowen immediately received their order for a further supply of tubes. Such indisputable instances as this furnish convincing proof of the soundness of the opinion which we have all along expressed in favour of the Field system, which, we are glad to hear, is making great progress abroad as well as in

Fig. 5.



our own country. In applying the Field tubes to egg-ended boilers, such boilers are placed at an inclination of about 1 in 12 from the horizontal, and all deposit is thereby thrown into a receptacle at the back, provided for the purpose, from whence it is blown off in the ordinary manner."—(See figs. 5, 6.)

Fig. 6.



5. *The Harrison or Cast Iron Sphere Boiler.*—Some two or three years ago, attention was drawn to this form of boiler, and considerable discussion elicited as to its merits. These were very highly spoken of by competent authorities (see p. 3. vol. of Engineering Facts and Figures for 1864) and several examples were introduced into practice in this country. In process of time, however, the results of trial here were very unsatisfactory. It is curious to note, however, that the results of practice in America (from which country the invention emanated) seemed to point in a very different direction. The fact at all events remains for consideration, that in America this form of boiler is largely used. The following, bearing upon the whole question, is worthy of perusal:

"*Report of the Committee on Science and the Arts, Constituted by the Franklin Institute, on the Harrison Steam-Boiler, Invented by Joseph Harrison, jr., Philadelphia, Pa.*

The Committee to whom was referred the examination of the 'Harrison Boiler,' report that, on Tuesday, October 30th, 1866, they visited the foundry of Mr. Joseph Harrison, jr., Philadelphia, and had an opportunity of inspecting the boilers in various stages of manufacture, and of seeing several in operation.

Experiments were tried to prove the strength and durability of the boiler, under extraordinarily severe use.

These boilers are of cast iron, formed of a combination of hollow spheres each eight inches diameter externally, and three-eighths of an inch thick, connected by curved necks three and one quarter inches diameter. These spheres are held together by wrought iron bolts, and in one direction are cast in sets of two, or four, with opposite lateral openings to each sphere, and are called by the inventor two or four-ball units, as the case may be.

He assumes that the boiler, in its smallest form, may be considered as one of these balls, with its opposite lateral openings closed by caps held in place by bolts. Two balls united by a neck, with caps over the four lateral openings, in the same manner would also make a boiler of a larger size. Four balls so united in one casting would be a still larger boiler, and that any number of these balls or spheres may be united by bolts passing through them so as to form large boilers, and the strength of the boilers so made will be the strength of the weakest sphere or ball in the structure.

In manufacturing the boiler for ordinary use, a number of these units are generally so arranged, as to form sections twelve and thirteen balls long, six balls wide. These sections are all tested by hydrostatic pressure, as high as three hundred pounds per square inch, before being delivered to purchasers. The Committee saw one of these sections subjected to a bursting pressure of water, one sphere bursting when the pressure had reached six hundred pounds per square inch. A second one, tested in the same manner, burst at six hundred and twenty-five pounds. They were shown a section in which one unit had burst at nine hundred pounds per square inch, the damage having been repaired by the insertion of a new unit. The section then stood eleven hundred pounds per square inch before bursting in a new place. The available strength of the section in all cases being the strength of the weakest unit in it, the inventor holds that the boiler is safer than any other in use; in fact, he considers it entirely free from danger of disastrous explosion. To prove which, he had a section equal to six horse power, similar to the one tested by hydrostatic pressure, and such as he is regularly selling, placed in an extemporary furnace built in a clay bank, and set in the usual manner for a boiler of this kind.

The boiler was filled with water to the regular height, say about two-thirds full, with no outlet or safety valve of any kind, and sealed up tight, a small tube leading from the upper ball to a high pressure-gauge, placed at a safe distance, say about two hundred feet from the boiler. A fire was made under and around the boiler, with the fuel of dry pine wood. The wind was very high at the time of the experiment, blowing from the west directly into the furnace, thus fanning the flames to an intense heat.

The gauge soon gave indication of the formation of steam, the pressure steadily increasing up to four hundred and fifty pounds to the square inch.

At this pressure there seemed to be a sudden discharge of steam, as from a small opening. The discharge did not continue for many seconds, and the committee are not certain that it proceeded from the boiler; there may have been some water discharge from the bank of wet earth into the fire. The pressure then increased at a uniform rate until it had reached the enormous strain of eight hundred and seventy-five pounds per square inch, when a sudden discharge of steam took place, seemingly no greater in volume than might issue from a safety valve of two and a half inches diameter, or even less; after which the pressure fell to four hundred and fifty pounds, at which it stood when the fire was drawn for examination. While this boiler was being uncovered for examination, a boiler of about twelve horse power, consisting of two sections, similar to the ones previously experimented upon, was fired and steam raised to one hundred and twenty-five pounds pressure. This boiler had no safety-valve, but was provided with a globe valve of one inch capacity or area, as an escape valve to regulate the pressure in the boiler. When the committee examined this boiler at the time of firing, it had two full gauges of water, the escape-valve was opened so as to reduce the pressure to one hundred pounds per square inch, and regulated from time to time to keep the pressure uniform at this point. The fire was pushed, and no more water was injected into the boiler. In due time the lowest gauge cock gave no indication of water. Soon afterward a slight leak was observed in one joint of the left-hand section. This closed in a few minutes and one opened in a similar manner in the right-hand section; this also closed in a short time. No other leaks showed themselves during the experiment. As the water boiled away, the soot began to burn off the upper balls of the sections, that is, off those of the upper balls of the lowest row, visible through a peep-door above the fire-door provided for inspection. The boiler then became gradually red hot, and even when all the water seemed to be exhausted, and the pressure slowly fell, the gauge stood for some minutes at thirty pounds as if from the vaporization of some water in the lower courses of the sections, showing that in this red-hot condition, the boiler was tight enough to hold pressure. After the fire had been drawn, and the boiler cooled, the bolts holding the units together were found to be loose, as if stretched by the unusual heating of the cast iron surrounding them. During the time of the experiment with low water, the escape cock was many times closed to increase the pressure, then opened quickly to reduce it to the one hundred pound standard, but with no deleterious result. When the gauge stood at thirty pounds, all of the boiler visible from the peep-door and fire-doors, down to the bridge-wall of the furnace, was at a bright red heat. This was unmistakable, as when the fire was drawn, the boiler was hot enough to ignite a piece of wood held against it.

November 13, 1866.—At four o'clock P.M. the committee met at the factory, J. Agnew and J. C. Cresson present. They examined the boilers tested at the former meeting. The boiler which had been subjected to its own steam-pressure of eight hundred and seventy-five pounds per square inch, had been removed to the factory for examination. Mr. Harrison's foreman stated, that when the boiler was first dragged from the fire, after its water had been forced out (as detailed in the account of the experiment), the three lower bolts were quite slack, but the next morning, when it had become cold, one of them was again tight. The other two were not quite tight, but were then screwed up about one turn of the nuts. The committee are confirmed in their belief that in this extreme test, the pressure at eight hundred and seventy-five pounds was enough to stretch some of the the bolts, that the joints opened as safety-valves, and thus relieved the strain on the boiler.

The boiler which, in former experiments, had had all its water boiled out and had been heated to bright redness, was found to be quite sound and fit for use, making steam freely and showing no leak, blowing off at sixty-five pounds by the safety-valve. It was somewhat disfigured on its outside by oxidation. Your committee was informed that it had not been changed or repaired since the trial, but that some of the bolts had been screwed up.

A third boiler, of the same size as the above, twelve horsepower, was then tested in the following manner: after being filled with water to the upper water-line, it was fired until pressure was raised to ninety pounds, at which it was blowing off freely. The water was then all blown out by the blow-off cock, the pressure falling to sixty pounds while blowing off. at which it stood until steam reached the blow-off pipe, when the pressure fell to zero. It was kept empty for three minutes with the fire still burning, and was then rapidly filled with cold water, and steam raised to one hundred pounds pressure in thirty minutes, blowing off at one hundred pounds, and was quite sound and tight.

The committee was informed by one of its members, who was witness of, and cognizant of, all the facts, that at the establishment of Mr. Wm. Sellers and Co., of this city, a boiler of this kind has been in use for about two years. During some experiments in testing the Giffard injectors made by that firm, a workman inadvertently loosened a connection to the water supply pipe, resulting in the pipe blowing full open, discharging the water from the boiler as fast as a two-inch diameter opening would allow, the men in the boiler-room barely escaping with their lives. As soon as all the water had blown off, and access could be had to the boilers, the fires were drawn and cold water run in as fast as possible, and, in about thirty minutes, the steam was high enough to run the engine, with no seeming injury to the boilers.

The committee mention this as an accidental experiment, similar to the one above reported. The same boiler is still in use, and seemingly as good as when first erected. It is, however, the first one erected in this country from units made in England, and is not so good as those made since then. On Saturday, November 17th, Mr. Harrison repeated an experiment in presence of a part of the committee, Messrs. Agnew, Morton, and Sellers, which experiment, he stated, had been tried twice the day before and once two days previous, all the experiments being with the same boiler. The experiment, as witnessed, was as follows:—

The boiler which had been under experiment November 13th was fired up, and steam raised to one hundred and ten pounds.

The fire was active—what might be called a very clear fire—and in good condition to make steam freely. It had been kept up sufficiently long to thoroughly heat all the furnace walls. Steam was blowing off freely from the safety-valve. At a given signal, the blow-off cock was opened suddenly, blowing off all the water until the pressure had fallen to zero, and neither steam nor water was escaping from the blow-off cock. In fact, it is believed the boiler was entirely dry. The blow-off cock was then closed, and cold water from a well pumped rapidly into the hot boiler, for it was at all times exposed to the active fire. As the water entered the boiler, the pressure, as per gauge, rose slowly during an interval of about three minutes, when, it is supposed, the water level had reached the more heated portion of the boiler above the bridge wall of the furnace, for the pressure seemed instantly to increase to the hundred and ten pounds, and steam blew freely from the safety-valve.

This pressure and escape of steam continued for some minutes with no variation, when suddenly an escape of steam was evident from the boiler into the furnace; and upon opening the peep-hole door, a jet of water was seen issuing from one of the joints. This leak, in less than a minute, suddenly stopped; then, as the water rose in the boiler, a similar sudden leak and sudden stoppage occurred at the next higher joint; again, at a third one, when, by that time, the water was showing itself at the lower gauge-cock, soon afterwards at the second when the pump was stopped, at which time the pressure stood at one hundred and ten pounds, steam blowing off freely from the safety-valve. The fire was as active as when the experiment began, and the boiler perfectly tight. This experiment, as before remarked, had been repeated three times previous to the one witnessed by the committee, and Mr. Harrison's account of the previous experiments, given to your committee, agreed in every respect with the facts as seen by them. This is as severe a test as any boiler is ever accidentally caused to sustain, and is, in fact, the one most likely to occur from carelessness. It is also testing, practically, the favourite theory to account for explosions. During the experiments, the employees of Mr. Harrison seemed quite fearless in their manipulation of the boilers, showing a confidence in their safety truly remarkable. With the exception of the single boiler sealed up and submitted to the extreme pressure of eight hundred and seventy-five pounds to the square inch, all the experiments were tried within the building in which the boilers are made, and any explosion would have resulted in serious loss of property if not of life. Had any ordinary wrought-iron boiler, made in the simplest form, and of the best material, been submitted to these same tests, it would have probably been destroyed by any one of them. Regarding the liability to accumulation of sedimentary deposit in this kind of boiler, we can only say that it is asserted by those who have used them the longest, that by occasionally blowing out the water under a full head of steam, then allowing the empty boiler to be moderately heated by the hot furnace, filling up with water and rinsing out, the scale becomes detached, and rushes out at the blow-off cock.

The committee have carefully inspected the manner of making these boilers, as practised by Mr. Harrison, and find the greatest care is taken to insure perfection of workmanship; but at the same time it is eminently noteworthy that the peculiarities of the boiler, and its mode of manufacture, are such as to enable a high degree of mechanical excellence to be obtained by mechanical devices, apart from the workman's skill. Thus, in the process of casting, taking as an example a four-ball unit, the four eight-inch spheres united by necks 3¼ inches diameter, internally, have on each ball two opposite lateral openings, 3¼ inches diameter, thus making in all eight openings to four balls. The patterns are all of cast iron, parted lengthwise through the centre of the unit by a plane at right angles to the lateral openings, these serving as supports to the green-sand core, which is moulded within the pattern itself, and not in a separate core box, thus insuring absolute uniformity to the thickness of the metal, and offering a more yielding core to the contracting metal than in the case of dry-sand moulding. The lateral necks which are to serve as joints in combining the units into the boiler structure are faced off by machinery of the most ingenious kind, so arranged as to insure neat accuracy in the surface, the joints on one side having depressions to match projecting tongues on the other, these tongues serving, with the longitudinal bolts, to hold the units in position. One of the most thorough descriptions of this kind of boiler is the report of a paper read by Mr. Zera Colburn before the Institute of Mechanical Engineers in 1864, an abstract of which can be found in 'Engineering Facts and Figures,' by A. Betts Brown, for 1864. He shows that although the tensile strength of cast iron is not so great as wrought iron, yet the spherical form of each unit of the boiler gives it an equivalent strength. He says, 'The strength of a hollow sphere to resist internal pressure is exactly twice that of a hollow cylinder of the same diameter, material, and thickness, and it can be shown that even a cast-iron sphere, seven feet in diameter and seven-sixteenths of an inch thick, is as strong as the shell of a Cornish boiler of the same dimensions.' 'The plane in which rupture, if it happen at all, will take place in a hollow sphere, is the largest plane that can be drawn through it, and the metal resisting the strain tending to cause rupture is the whole section of metal bounding the plane.' 'In a hollow cylinder the area upon which the greatest pressure tending to cause rupture will be exerted is that represented by the product of the length into the "diameter of the cylinder."' The ends of such a cylinder add nothing to the strength of the cylindrical part, in case of a rupture beginning at the cylindrical part.* The spherical form of each part of this boiler is one of its marked advantages, not only so far as strength is concerned, but as enabling a much larger amount of surface to be exposed to the fire than in any form of combined cylinder. To the spherical form with the curved necks has been ascribed by the inventor the property, which this boiler is asserted as having, to cast its scale when emptied of water, as there is no seeming abutment for the arch of the crystallized scale to spring from.

The value of cast iron, so far as durability is concerned, has long been conceded. The purer the iron the more readily does it corrode, while the mixture of even a small amount of carbon increases its ability to resist corrosion. Wrought iron water pipe under ground soon rusts out. Cast iron, even of the same thickness, remains good after many years' use; in fact, is considered practically to suffer no deterioration. Wrought iron in boilers decays internally—the most rapidly where moisture and air both operate, as in the upper side of mud drums, while they are often eaten through from the outside by trifling leaks, and the constant trickle of water over the surface. Wrought iron boilers are, according to the experiments of Fairbairn and others, so much weakened by the process of riveting, etc., as to suffer a deterioration of about forty per cent. The Harrison boiler is made of pieces of as uniform strength as possible, united in a systematic manner. The uniting the units or pieces into mass, does not diminish their strength. In case of accident to any part of the boiler, the damaged part may be removed, and, instead of being repaired, as is done with wrought iron boilers, new parts may be substituted, just as bricks may be taken out and new ones replaced in a building. The patching of a damaged wrought iron boiler makes it weaker. The renewal of any part of the Harrison boiler gives it its original strength.

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* The metal effectively resisting the rupture in the cylinder being only the length of the cylinder. Thus, by comparison, Mr. Colburn arrives at his conclusion as to the relative strength of the two forms.—See *Engineering Facts and Figures*, 1864, pages 12 and 13.

The experiments heretofore described have been conducted to determine the safety and durability of the boiler under unusual and severe usage, or, rather, to determine whether any danger can result from submitting this kind of boiler to those circumstances which, in ordinary wrought-iron boilers, are thought to result in explosions or great injury to the boiler.

The committee are impressed with the great utility of the boiler, as one perfectly safe, and free from all danger of explosion even when carelessly used. This recommendation alone, in a humanitarian point of view, must strongly recommend it to public favour. During the experiments its steam-making qualities were favourably noticed, and such boilers in actual use as your committee have had an opportunity to examine, seem to give satisfaction in point of economy; but, in the absence of all experiments in this direction, conducted under their immediate supervision, they do not feel qualified to report in figures as to its steam-making efficiency.

Comparing cast-iron plates with wrought-iron ones of the same thickness, the transmission of heat is known to be in favour of the former; hence the material, if in a safe form, is better adapted to economical steam-making than wrought iron. Ordinary boiler plate is seldom less than one-fourth of an inch thick, and more commonly three-eighths, particularly for high pressure. The castings used in the experiments for safety were not over three-eighths of an inch thick, and in one boiler set up in a form adapting it to marine purposes, some of the units were only three-sixteenths of an inch thick, and were worked successfully at one hundred pounds pressure, driving all the machinery in Mr. Harrison's factory in an efficient manner. The principle of enlargement of the boiler by the addition of units, and the fact that it can be constructed in any shape or style, just as various kinds of buildings are constructed of ordinary bricks, places it in the power of the engineer to adapt it in its form to the requirements of each particular case; so that with the known advantage of the use of cast iron, and the unlimited scope in the arrangement of heat-absorbing surface, coupled with the demonstrated fact of safety, your committee unhesitatingly approved and heartily recommend it to public favour.

Sub-committee appointed to make the examination:—Coleman Sellers, chairman, John Agnew, John F. Fraser, Henry Morton, J. C. Cresson."

6. *Martin's Boiler.*—The following description of this boiler —which is favourably known to American engineers—is from Mr. V. Pendred's paper on "Water Tube Boilers,"—already quoted from:—

"It has been extensively used for some years—all the vessels of the Collins' line were at one time fitted with it—and it apparently deserves the good character which it enjoys. In principle it bears a strong resemblance to Galloway's boiler. The author has selected for illustration a boiler fitted on board the American sloop San Jacinto, the diagram being enlarged from a cut given in 'Experimental Researches in Steam Engineering,' by Mr. Isherwood, chief of the Naval Bureau of Steam at Washington; in other words, Mr. Isherwood is engineer-in-chief of the entire U.S. navy. In the course of his proceedings it became advisable to determine the relative qualities of the Martin boiler and the ordinary fire-flue boiler, and the experiment was carried out in the following way:—The San Jacinto is fitted with two boilers arranged at opposite sides of the stockhole, and delivering into a single chimney common to them both. One of these boilers is a fire-flue, and the other a water-tube generator. In external dimensions and characteristics the boilers are identical; the shell, in general form, is rectangular, the flat tops, sides, and ends being united by quadrantal arcs of 30 in. radius, while the sides are united to the bottom by arcs of 18 in. radius. Each boiler has six furnaces, 3 ft. wide and 6 ft. long on the grates; the height from the bottom of the ash-pit to the crown of the furnace is 42 in., the distance between the crown plate and the bars in front is 20 in., at the back 28 in. A combustion chamber 19 in. long runs back to the hinder uptake; its shape is shown in the diagram; it is 18 in. high in the lowest place, and is 3 ft. wide. Each combustion chamber delivers into a distinct uptake 3 ft. wide, 18 in. long, and 5 ft. 2 in. high in the clear. Its shape in cross-section is shown in the diagram. From this back smoke connection or uptake, in the fire-flue boiler, the tubes run above the furnaces in the usual way. They are of brass, 3 in. diameter outside, and 6 ft. 11⅛ in. long between the $\frac{9}{16}$ in. thick tube plates, in which they are secured without ferrules by the expanding mandril. The tubes for each furnace are distributed into eight rows horizontally and nine rows vertically, except for the two centre furnaces, which have only horizontal rows to allow for staying. The uptake is common to all the six furnaces, and requires no particular description. During the experiments, a kind of louvre of plate iron was placed above the upper row of tubes, in order to retain the gases in the upper rows of flues 'until the heat was more abstracted from them than it would be without its assistance, as experiment has shown the draft to be more rapid through the upper than through the lower tubes.'

The water-tube boiler is shown in section through one furnace in the diagram (not given here). It resembled the fire-flue boiler in every respect, with the exception of the tubes and covers. It will be seen that instead of fire tubes the products of combustion are led through a rectangular box from the back to the front uptake. This box corresponds in a measure to the flue of a Cornish boiler, and the requisite heating surface is supplied by a great number of vertical tubes connecting the top and bottom of the box. The water enters these at the bottom and rises to the top. A constant upward current exists within them, while a downward current exists between the tube boxes and the back and sides of the boiler. In the diagram the tubes are drawn, for the sake of clearness, to a much larger scale than the rest of the boiler. This much premised, we may return to the more particular description of the San Jacinto's boiler, as given by Mr. Isherwood.

The tubes are contained in boxes 36 in. wide in the clear, and 32 in. high, and of sufficient length to allow the tubes to occupy a space 7 ft. long. The tubes are secured with the expanding mandril, and without ferrules. There is one tube box to each furnace, and it is made of ½ in. iron plates. The space between the furnace crown and the box averages 10 in. The water space between the boxes is 4 in. wide in the clear, and between the end boxes and shell 7 in. Each box contains 270 brass tubes, distributed in ten rows across and twenty-seven rows lengthwise of the box. Each tube is 2 in. diameter and 32 in. long, clear of the plates; the tubes are set so as to break joint and not in direct rows. That this is an important feature has already been pointed out. The space between the tubes is, lengthwise 1 in., crosswise 1⅜ in. A hanging bridge was placed in front of the tubes to impede the velocity of draft, for the same purpose as in the case of the fire-flue boiler. The annexed table gives the comparative dimensions of the two boilers.

	Fire-tube boiler.	Water-tube boiler.
Breadth of boiler, . . .	21 ft. 3 in.	21 ft. 3 in.
Length of ditto (athwartship),	11 ft.	11 ft.
Height of ditto without steam drum, . . .	11 ft. 3 in.	11 ft. 3 in.
Number of furnaces, . .	6	6
Aggregate grate surface in square feet, . .	108	108
Number of tubes, . . .	414	1620
External diameter, . . .	3 in.	2 in.
Length of the tube between plates, . . .	83⅛ in.	32 in.
Heating surface of tubes measured inside for the fire-flue and outside for the tubulous boiler, . .	2,078·92 sq. ft.	2,332·64 sq. ft.
Total water-heating surface, .	2,663·8 sq. ft.	3,295·25 sq. ft.
Diameter of chimney, . .	6 ft. 4 in.	6 ft. 4 in.
Height of ditto, . . .	51 ft. 6 in.	51 ft. 6 in.
Calorimeter, . . .	16·84 ft.	16·84 ft. at front and 21·55 at back of boiler.
Weight of boiler, . . .	86,412 lb.	86,860 lb.
Of water in ditto, . . .	46,600 lb.	39,200 lb.

The foregoing will, the author hopes, make the principal peculiarities of the Martin boiler perfectly clear, and will supply all the data necessary for arriving at a distinct estimate of the value of the results obtained by Mr. Isherwood, which the author proposes to consider. The details are given at great length in the second volume of 'Experimental Researches;' at a length, indeed, which renders it impossible to reproduce the particulars in their entirety here, and the author must, per force, rest content with placing before his readers little more than the results at which Mr. Isherwood arrived.

The evaporative efficiency of the boilers was determined directly by their evaporation of water at atmospheric pressure while the vessels lay alongside the wharf. The boilers were first opened and thoroughly cleaned; they were found to be perfectly free from scale, as the engines were fitted with surface condensers, and they were quite tight. The chimney, or smoke pipe, was divided during the experiment by a partition of sheet-iron reaching from the bottom to such a height that the draft was quite independent for each boiler. The steam escaped from the boilers through escape pipes 16½ in. in diameter, bolted on to the side of the stop-valve chests, from which the valves were removed; provision was made to prevent the return of condensed water.

The experiments were carried out to test the value of various calorimeters and rates of combustion with both natural and forced draught. The author regrets that the details are too long to reproduce here. It is more than he can do to say all that might be said about the efficiency of the boilers compared with each other, and it is simply impossible to consider at any length the efficiency of each boiler as compared with itself under different conditions of draught, &c.; it must suffice to say that the way in which the coals were weighed and the water measured left nothing to be desired, and that the general results were as follows:—

1st. With equal calorimeters the maximum rate of combustion by natural draught was less by 8⅛ per cent. with the water-tube boiler than with its fellow.

2d. In America it is the practice to give more calorimeter with the water-tube than with the fire-tube boiler, and adopting normal proportions in this respect the rate of combustion was greater by very nearly 3 per cent. in the water-tube boiler.

3d. When equality of grate surface in equal shells is disregarded, and the ratio of the heating to the grate surface made equal, the economic evaporative efficiency of the water-tube boiler exceeded that of the fire-flue boiler by 8·1 per cent. This result was only obtained, however, by reducing the grate surface of the fire-flue boiler 22 per cent., which was tantamount to employing a much larger boiler.

4th. Under the proper comparable conditions of equal grate surfaces in equal shells and best proportions of calorimeter, the economic efficiency of the water-tube boiler was better than that of the fire-tube boiler by 14·79 per cent. This is of course the true commercial estimate, as it represents the values to be obtained from two different boilers of the same size, weight, and cost.

5th. As regards the power of producing a large quantity of steam in a short time it was found that with the quickest combustion to be had with a natural draught the water-tube boiler evaporated 12·2 per cent. more water in a given time than its rival. But reducing the grate surface of the latter so as to make the ratio of heating surface to grate surface the same in both, the water-tube boiler beat the fire-flue boiler by 27·6 per cent.

6th. The best calorimeter for both boilers was the same, $\frac{4}{31}$sts of the grate surface.

7th. The water-tube boiler evaporated from the temperature of 212 deg. 10·853 lb., and the fire-flue boiler 9·902 lb. of water per pound of anthracite coal burned."

6*a*. *Tubulous as compared with Cornish Boilers.* The following are the remarks upon this subject of Mr. Prendred in his paper above quoted from. "The author has already drawn a comparison between the water-tube and the Cornish boiler, and in the foregoing is given the result of a careful comparison between it and the ordinary tubular marine boiler. In this, as in every instance, we find that the superiority of the water-tube boiler as a generator is distinctly proved. In theory, as the author has endeavoured to show, the water-tube boiler is the best, because it permits of an arrangement of the heating surface which is incompatible with any fire-flue boiler. Theory asserts that a certain disposition of surface, which will break up the gas currents, is the best. Practice proves not only that theory is right, but it does more. It demonstrates that no other form of generator save that which embodies the princip of including water in small tubular subdivisions can comply with the required conditions to perfection. Regarded merely as a steam generator, the water-tube boiler is in theory the best, and practice demonstrates that when properly designed and put to work it can be made to succeed. But beyond all this a point arises for consideration of overwhelming importance. There is an increasing tendency on the part of engineers to use higher pressures; and whether from this cause or some other more occult, it is clear that, notwithstanding the labours of the inspection and assurance societies, the number of explosions is rather on the increase, and they are, as a rule, attended by a fearful destruction of life and property. Dr. Alban was the first to enunciate the proposition that nothing can prevent boilers from exploding, but that the engineer could easily construct them, so that the explosion would not be dangerous. This can be accomplished with the tubulous boiler, but with it alone. The quantity of water it contains is moderate, and we know that the violence of an explosion depends on the quantity of water within the boiler at the time, and on its temperature. From the nature of the communication the fracture of a single tube need not be attended with any serious consequences, as the water and steam have comparatively small orifices through which to escape. The collapse of a tube in the Martin boiler would be productive of no fatal consequences. Tubes as large as those used by Mr. Howard have given way repeatedly in Alban's boilers without doing the least harm. This is a most important point in favour of the tubulous boiler; and what can be urged against it? Experiment daily demonstrates that there is no insuperable objection to the water-tube boiler, yet comparatively little or nothing is known about it by engineers or boiler makers, and although the author believes that the principle has a great future before it, the subject is very far indeed from having as yet received the attention it deserves. Water-tube boilers have repeatedly failed because they were complex and fragile, resembling delicate philosophical instruments rather than practical steam generators. The real bearing of the questions connected with the generation of steam begins to be better comprehended, and the author regards the already extended and rapidly growing employment of Galloway and Field tubes as a hopeful sign. Any one who visits the Paris Exhibition will see what Mr.

Howard has accomplished; and those who wish to try to produce for themselves a good steam generator will find that if they only pay strict attention to the rules laid down by Dr. Alban, and quoted in the early part of this paper, a successful result will be secured. If it is not, the engineer may rest assured that it is himself, not the rules which are at fault.

In conclusion, the author wishes to observe that as no attempt has been made to give a history of the water-tube boiler, the names of many ingenious men have been left unmentioned. Those of his hearers, however, who have in any way entered into the spirit of the paper will perceive at once that the mere recording of names was quite foreign to its scope and purpose. The author has endeavoured to deal with principles not with men, and he has only selected the different boilers mentioned as illustrating the best modern applications of those principles. That the paper while lengthy is far from being complete no one is more fully aware than its author. If it serve to draw attention to a most important and interesting subject, and to promote the cause of the safe and economical tubulous boiler against those old-fashioned generators which, while neither so economical nor so safe, hold their position by prescriptive right instead of actual merit, he will be content with the result of his labours."

7. *Leslie's Gas Burning and Superheating Boiler.*—"The combustion of the gases evolved from fuel and the proper distribution of heat in a steam generator is a desideratum to obtain which many attempts have been made. The boiler, a longitudinal section of which is presented in the engraving, is intended to accomplish this result. As will be seen, the grate surface is very much larger in proportion to the water surface than in ordinary boilers. Projecting above the grate and covering a portion of it is a water leg acting as a bridge wall. Against this the flames impinge and partially envelope it; then the flame, smoke, and gases follow the direction of the arrows down through the vertical tubes to the lower combustion chamber into which, through suitable apertures, governed by dampers, a proper quantity of atmospheric air is admitted to aid in the combustion of the gases, when the products pass upward through the back tubes to the smoke stalk. These tubes may be carried as high above the water level as desired, to superheat the steam. On the t

of the boiler a dome of any required form and dimensions may be placed.

To this boiler either the horizontal or vertical system of tubes or flues may be applied, or both may be combined in the same boiler. The addition of a combustion chamber for the purposes of consuming the gases, after they have left the furnace proper, is considered by the inventor superior to the device of burning them in the same chamber with the solid fuel. He claims that a good circulation of the water is insured by the peculiar construction of the boiler, and that the sediment will be deposited at the sides, from whence it can be readily removed at the hand-holes. Those boilers of this style now in use, steam easily and rapidly, and the furnace can be adapted to all sorts of fuel, bituminous and anthracite coal, wood, shavings, sawdust, and coal dust. It is claimed that the water level will change very little with irregular feeding, and that the boiler never primes."—*Scientific American.*

8. *Marine Boilers.*—From a paper on this subject in the "English Mechanic," of Nov. 1st, 1867, we abstract the following:—"The principles pertaining to marine boilers are of the highest importance, and those who pass them as unworthy of notice are the most ignorant of their nature—indeed, so certain is this fact that we have known it to be said by some, 'Oh, anything will do for a boiler; that portion is the least consideration.' Now, before proving the value and the mode of producing a really effective boiler, let us notice the 'principles' that govern the same.

First, then, what do we require from a marine boiler?—or any other boiler, as far as that goes. Why, we require a certain amount of power, and that 'power' to be developed in the smallest compass, and in the most economical manner. The 'power' being in the form of steam, we must consider the best means of producing it.

Knowing, then, the amount of heat, the relative quantity of evaporation next claims attention. To begin with, let us consider the relative position of the water and the fuel, and the nature of the material that separates them. Looking at the sectional views of the boiler in the illustration, (not here given) it will be seen that each fire-box is separate from its neighbour, and all are surrounded by the water excepting at the mouth or front end. The fire-grate is inclined to better admit the air under it, and the width of the grate extends to the sides of the fire-box. Now, before we can judge of the evaporating properties, we must learn the action of the flame during its circuit or progress. Again, reverting to the longitudinal sectional elevation, we must imagine the fuel to be ignited and the flame rising. Now the action of the flame will depend on the draught attainable, and also the direction of the same. Presume, for example, the draught to be under the grate only, the action of the flame will be to rise at right angles with the inclination of the fire-bar, but if air be admitted over the grate as well as under it, then the flame will strike the crown of the fire-box in a curve-like form rather than impinging direct.

Keeping still the section alluded to in view, and following the flame, we shall learn that the sides of the fire-box above the grate receive a sliding contact, while the crown is more effectually operated on by the volume. Some authorities lay great stress on the idea, that the portion of the sides of the fire-box in contact with the fire must be of great value as evaporative surface. Unquestionably the portion alluded to is of certain value above the remainder of the sides, but in our opinion—which is based on natural laws—the crown of the fire-box is the main evaporating surface in the compartment under notice.

It will be noticed in the illustration (not here given), that the bridge is dispensed with, and that the termination of the grate is in contact with the rise of the combustion chamber. This arrangement is now universal, and much to our surprise was not long ago, for it is evident that the flame after passing the crown of the fire-box curls towards the tube openings, and the back of the combustion chamber, the least effective surface in that compartment, while the portion inclined from the end of the fire-grate, unless conforming with the action of the flame, is of little or no value for evaporation.

Suppose, now, the flame is in the combustion chamber—we must remember the tube plate is merely a perforated wall against which the flame acts. Now, the 'action of the flame on the tube plate' has not met with general attention by the authorities on combustion; they have either not alluded to it, or passed it with the slightest recognition. The author who has thrown most on the subject is Mr. Burgh, in his new work, 'Modern Marine Engineering,' in which he states, 'The bulk of the flame conforms to the required shape of tubular entry before arriving at the plate, this being due to the fact that the spaces between the tubes actually displace the flame. These spaces are also bases of cones, the apices of which are at the commencement of the division or alteration in the form of the flame. The cones are not, of course, presumed to be circular at the base, but rather of an octagon shape, thus conforming to the relative position of the tubes. The 'cones' are also doubtless hollow, at the base in particular, and therefore the actual contact of the flame on the surface is mainly at the cones' connections with each other.' This, Mr. Burgh says, is the general assumption. His ideas on the subject are these:—'The spaces between the orifices or tube openings are bafflers in the full meaning of the term. The flame does not voluntarily act on the tube plate, but is impelled towards the same. The flame conforms to the required shape, as before stated, before entering the tubes. Here a total disturbance ensues in the form of continual displacement of the volume against the plate, and the greater the draught the greater will be the impact. Hollow portions of flame are undoubtedly formed, but they are perishable, and constantly replaced by the following current. The hollows are curvous, and why? Because the flame that acts against the plate enters the tubes—not rests on the spaces between them—and therefore proceeding at right angles with the plate, it forms curves at the edges of the tubes.'

Assume, next, that the flame is now entering the tubes. We must next consider the action during its traverse to the smoke-box at the other end. Various and adverse are the opinions on the value of the tube-surface as an evaporative surface. The late Mr. C. W. Williams was an advocate for the tube plate as the main agent, and 'only the first part of the tube,' said he, 'is of any value;' while for thus maintaining he raised a hornet's nest of opinions contrary to his own. In the present day, however, we are pretty certain about the matter, as the tube itself is the best teacher. We know now that the upper half of the tube receives the greatest impact of the flame; and we are aware, also, that the longer a tube is, the more the *time* for evaporation.

Now, then, for the practical question; the passage of the heat from the fuel through the metal acted on by the flame, and the absorption of the heat by the water. Now let us look the matter full in the face, without assumptions or conjuring up difficulties, but take a plain view of the case in order to arrive at the truth. Here we have fire in a furnace, and that furnace is surrounded by water; we require if possible to absorb the heat as fast as it is generated, to convert the water into steam.

Again, another fact presents itself: All the heat that passes into the water must penetrate the plates or tubes, as the case may be, and therefore the conductive properties of the material are worthy of attention.

Now were there *no* absorption of the heat in a boiler the temperature of the volume at the uptake would be the same as in the combustion chamber; it therefore is requisite to remember this, and thus arrange the boiler for the water to absorb as much heat as possible, before the flame or heated product reaches the chimney. How many of our readers have not noticed on a winter's evening flame proceeding from the chimney of a steamer instead of smoke in a mild form. There was a loss of heat, a non-absorption, a waste of fuel, and an evidence of bad arrangement combined with ignorance of the designer. What we must consider is this: A certain quantity of fuel has a certain amount of heat in it, and we should absorbe that heat by the water, and thus convert the maximum amount of steam than otherwise.

To return to the actual passage of the heat through the plate and the absorption by the water. Here we must remember that a certain volume in a gas-like form is on one side and a liquid property on the other; as fast then as the heat is allowed—we say especially 'allowed,' because the time for the conduction and absorption is the main feature in the case—to pass through the plate, corresponding will be the generation of the steam. Thus, for example, if the heat is allowed to slide over the surface of the plate instead of dwelling on it, the 'time' for absorption is reduced, and thus the continuous amount of absorption reduced also. Indeed, so far is time the most important question, that we find in the present day nearly all boilers are constructed, or rather arranged, in recognition of this fact, by making the combustion chambers larger and the tubes longer than formerly. Directly the heat passes the plate or tube the water lays h of it, and the heat ascends to the water line, where it is flashed into steam. Now then, about the certainty of this; a common teakettle will explain it. The bottom will always be cooler than the top or at the water line, simply because the heat ascends to produce the steam. The conversion of the steam from the water certainly commences at the bottom, or over the fireplate, but the completion is at the water line, at which locality the steam commences. The conclusion, then, on this part, is this—that steam is a combination of heat from the fuel and the water in the boiler turned into a gas, and therefore the greater the heat produced the more steam can be generated, and the pressure therefore depends on the temperature of the steam and fuel.

Now we may as well allude, before closing this section, to the advantages and abuses of superheating steam. First, then, why do we superheat steam? There must be a reason certainly, or doubtless we should not take all the trouble we have about the method. This is the answer, Steam generated in its natural form direct from the water, is composed of minute globes of water filled with steam, and therefore termed saturated steam. The advantage, therefore, of superheating is to dry the steam, or still further, to cause more pure steam than in its original state.

Now, some people may be incredulous about the globes being framed of water as we have mentioned. For their benefit, therefore, we will easily explain a little further. As the heat rises from the fire-box plate or any other heated surface, it is absorbed by the fluid above it, and just like air ascending in water, globes are formed; or like, if you still wish a more domestic occurrence as an example, a little boy blowing soap bubbles; in either case the fluid is the globe and the gas is contained within the same. Further, if requisite, the damp spray from the spout of a teakettle, or from the waste steam pipe of a high-pressure engine or marine boiler.

Although superheating steam is essential, the advantage can be abused by overdoing the matter, *i.e.*, superheating at too high a degree of temperature, and thus cutting the working surfaces of the engine in contact with the steam. The total heat of the steam should not exceed 300° Fahr., if tallow is used as a lubricant within the cylinders.

The amount of water on the average evaporated from 212°

Fahr., with 1 lb. of fuel or coal, is about 10 to 12 lbs., considering all the foregoing conclusions.

General Arrangement.—The mode of commencing an arrangement for a marine boiler is first to learn the locality and the amount of room in the hull allotted. In our Government ships one of the leading rules is that the top of the boiler must be below the line of flotation. It was from this circumstance that low boilers were introduced for hulls of small tonnage and shallow draught. In the present day the hulls are mostly larger and deeper immersed than formerly, hence high boilers are almost the universal practice now. Presume, now, we have ample space for high boilers in the hull, and we know, also, the nominal power of the engines, our first step is to decide the ratio of the indicated horse power; and why? Because without sufficient steam the engines cannot work up to the required number of revolutions. Settling, then, the indicated horse power, we start with the grate surface, as it is from that area that the whole duty is originated. Now, then, to allude to the sectional elevations, in the one view the length of the grate is shown, and in the other the width and number of fire-boxes. The total length of the grate or fire-boxes should never exceed 7 feet; in the present example it is 6 feet 6 inches, the width being 3 feet. The area then becomes $6{\cdot}5 \times 3 = 19{\cdot}5$ square feet, and four grates $= 19{\cdot}5 \times 4 = 78{\cdot}0$, which, as the boiler is 100 horse power nominal, the area is ·78 of a square foot per horse power nominal, and $\frac{{\cdot}78}{6} = {\cdot}13$ of a square foot indicated horse power. Next come the tubes over the fire-boxes; first, the length must be decided, which is generally as long as the space in the shell will permit; in the present instance the tubes are 6 feet long, the combustion chamber 18 inches wide, and the water space beyond 4½ inches. The area of the tube openings must now be noticed, and in so doing we must not omit the principles governing that area. The flame that is in the combustion chamber has to escape from it, and, as the volume originated from the area of the fire grate, that surface must be considered in proportioning the area in question. The general practice is to acknowledge that the combustion chamber should always be filled with the volume from the fire grate, and thus the area of the tube opening is

$$\frac{\text{area of grate surface}}{6{\cdot}75 \text{ to } 7}$$

Then bringing the area of one grate in the illustration into square inches we have 78 × 36 = 2808 square inches. To obtain the total area of tube openings for that grate surface, we have thus:—$\frac{2808}{7} = 401$ sq. inches; then as the inside diameter of each tube is 2¼ inches, the area of each tube opening 3·97—say 4 inches—proceeding then $\frac{401}{4} = 100$ tubes for each fire grate, which is that in the illustration.

Now for the tubular surface in square feet per nominal horse power; each tube is said to be 2¼in. in diameter inside, but the outer diameter is 2½ inches: then the circumference of 2½ inches in feet = 2082 × 3·1416 = ·6540 lineal feet; therefore, as the length is 6 feet ·6540 × 6 = 3924 square feet, or for the superficial area of one tube. The total number of tubes in the boiler is 400, then 3924 × 400 = 1569·6 square feet of tube-heating surface; and 100, the horse power nominal; then $\frac{1569{\cdot}6}{100} = 15{\cdot}696$ square feet of tube surface per nominal horse power, and $\frac{15{\cdot}696}{6} = 2{\cdot}616$ per indicated horse power, which is about the average proportion.

The pressure of the steam is 30lbs. on the square inch in the boiler. We have next then to consider the thickness of the plates composing the fire box, combustion chamber and shell. Now what is the nature of the strain to which the boiler plate is exposed; the pressure is inside, and its tendency is to bulge out the plates; therefore, tensile strain is the greatest function imposed on the plate. But we have riveted joints to contend with, therefore their breaking strain must be noticed also. The breaking strain of wrought iron plates on the average is 44800 lbs. on the square inch across the sectional area of the plate's thickness. The strength of the single riveted joint is about ·67 of the plate of equal thickness; then 44800 × ·67 = 30016 lbs. on the square inch, or the breaking strain of the single riveted joint. Considering then these facts, the mean breaking strain of the shell will be known thus $\frac{44800 + 30016}{2} = 37408$ lbs. for the average breaking strain per square inch of section. But we have to notice also that the plate is heated by the fire and steam, consequently its cohesive property is impaired. Now if we deduct one-third of the breaking strength when the plate is cold, we arrive at a fair value for the actual breaking strength of the heated $\frac{37408}{3}$ plate. Then $= 12469$ again $37408 - 12469 = 24939$ lbs. for the working breaking strain.

The shell and the internal compartments are stayed in the illustration, and therefore we must recognise, in our future calculation, the greatest length between the stays, which we will take as 30 inches angular measurement. As the pressure of the steam is 30lbs. on the square inch, $30 \times 30 = 900$, and $\frac{900}{24939} \doteq 0{\cdot}360$, which, multiplied by the factor of safety $12 = {\cdot}422$ for the thickness of the plates; but as the material cannot in all cases be depended on, half inch thickness for the plate was used in the example illustrated under notice.

The thickness or rather diameter of the stays is deduced from the following simple formula—

$$x \frac{a\ p}{s} \times f, \text{ where}$$

x = area of stay in square inches.
a = area of surface in square inches supported by the stay.
p = pressure of steam in lbs. per square inch.
s = the strain to be resisted.
f = factor of safety.

The super-heater next claims attention. In the illustration this apparatus is simply a cluster of tubes, surrounded by the steam, the heated products from the smokebox passing through the tubes. The stop valves and piping shown in the two views under notice regulate the traverse of the steam, inasmuch that if the super-heater be out of order, the steam can be supplied from the boiler direct to the engines. On looking at the plan, the super-heater, tubes, firebox, and grate will be better understood relative to several positions.

The stays, it may be added, in passing, are secured by nuts in all cases in this example, but in some instances T iron riveted to the shell, with double-eyed stays and pins, is sometimes introduced.

The arrangement of the chimney casings, &c., will be readily understood from the sectional view of the same, at the side of th sectional elevation of the boiler, also the means for raising and lowering the chimney.

Details.—The safety valves of a marine boiler being of the utmost importance, we present our readers with two examples, one outside loaded and the other inside, or suspended load. The illustration, being taken from the working drawings, we need not explain them more than requisite in the formula thus, let

x = weight of load and valve.
a = area of valve in square inches.
b = pressure of steam per square inch.
c = pressure against the valve or the resistance.
d = cubical contents of weight, minus the weight of the valve.
e = area of weight.
f = length of weight.
g = weight of a cubical inch of the material of which the weight is made.

Then—

a = total area of fire grate.
$c = a \times b$.
e = area of $a \times 4$ in some cases, but generally according to circumstances.

$$f = \frac{d}{e}$$

$$x = e \times f \times [g - \text{weight of valve.}]$$

The above matter is indeed merely a calculation of the simplest order, as levers are dispensed with and the load direct, whether it be outside or inside the boiler.

The section of the stop valve explains itself without description.

We are indebted to Mr. Burgh for the illustrations, they being examples of his practice." (For these see No. of 'English Mechanic' for Nov. 1, 1867.)

9. *Welded Boiler Joints.*—"During the past few years many efforts have been made to do away with the lap and rivet system of joining boiler-plates; one great objection to the system of riveting being the corrosion of the plates on the interior of the boiler, where the line of rivets join the plates together. When boilers are made of a single plate bent into a circle and having only one longitudinal riveted joint, it is some improvement, as it does away with the longitudinal laps that occur in the lap and

riveted boilers built up of sectional plates. This may be called the first step in the improvements in boiler making, and seems a sensible one, that ought to have been adopted when the manufacture of boilers first commenced. But until the time shall come when we will have seamless boilers of steel, rolled like a tube upon the machinery that 'is to be' in the future of mechanical skill, we are content to use the old style of lap and riveted boilers.

We find in this style of boiler two evils to contend with; corrosion of the plates by a chemical action, and corrosion and mechanical action combined. The first occurs in various parts of the boiler, and we find the surface of the plates irregularly pitted. But the last-named evil occurs along the line of the laps, both the longitudinal as well as the transverse joints, and occurs mostly below the water-line. Corrosion, it is true, can be accounted for by chemical principles; but when we find annular grooves running parallel or in the immediate vicinity of the riveted joints, we must look to some other cause, and must attribute it to the effects of heat upon the joints, and to the combined effort of mechanical and chemical action. We will suppose that a chemical action has commenced equally over the interior surface of the boiler; we find that the effects of heat upon the plates will be such that there will be unequal expansion where the laps occur; perhaps this may be accounted for in consequence of the plates not being in the same line of strain, and as the contraction is succeeding expansion the deposit of scale induced by corrosion is cracked and broken off. This lays the surface open to a similar succeeding action, which, in process of time, forms an annular groove, and destroys the strength of the plate at this point. The corroding action of the water upon the plate is quite weak compared with the action that goes to form these annular grooves.

Upon locomotive boilers this evil is much greater than in the stationary boiler, and for this reason the different supports and braces of the boiler are rigidly made, and they offer a great resistance to the expansion and contraction of the boiler, which has a greater tendency to throw off this scale and present new surfaces for corrosion than in any other kind of boiler. The system of forming boilers of a series of hoops or loops, with but one riveted joint, overcomes a part of this evil. Another plan has been used, with some success, of rolling the plates with the customary thickness of body, the edges tapering with a gradual thickness, by this means ensuring an equal springing of the plates instead of the concentration of force acting upon them at a single line. In this mode there is a gain of strength where the lines of riveting occur, as the loss of metal consequently weakens the plates by the series of rivet holes, but is compensated for by the additional thickness. It has been shown by actual experiment that boilers constructed upon this plan have been successful; no annular grooves being formed by corrosion consequent upon the mechanical action.

Welded longitudinal joints have been made with a fair prospect of success; but there is but little prospect of their ultimate adoption. In all experimental boilers of this kind that have been made, the weight was greater and the expense much more than any other kind of boiler. Instead of adopting *heavier* boilers, we are continually looking for a boiler that shall be lighter as well as cheaper, and combining the same amount of strength. The great want seems to be a boiler that shall be light, constructed of Bessemer or some kind of steel that shall be perfectly homogeneous—made seamless, perfectly cylindrical, and of length or diameter to order. When we call to mind the improvements made in steam hammers, and the huge forgings that are formed by their aid, the rapid improvements made in the manufacture of wrought iron tubes, can we not look to the future as producing boilers made in this manner and upon these principles? It may be of no greater difficulty in the future then the making of iron tubing has been in the past. Where there is a demand, or where a demand can be created, *there* genius will find a means to supply all that is needed or called for."—*American Artizan.*

10. *Boiler-Making.*—"It is of very little use," says 'Engineering' in a leading article, "preaching how a boiler ought to be made, unless we are prepared to show how a good boiler can be made in practice. We have selected Mr. D. Adamson's boiler works at Newton Moor, near Manchester, as one of the best examples of their kind for the purpose of placing the present state of boiler-making practice, and the next progressive steps which are likely to be taken in the manufacture of boilers, before our readers. Mr. Adamson has been led to

boiler-making as a speciality by his well-known patent for flanged seams, and his experience having been collected by the manufacture of nearly one thousand boilers, he is now considered one of the first authorities on boiler-making in this country. The main principles arrived at in the Newton Moor works are the following: To test every plate used as to its tenacity and ductility, to use no single row of rivets for longitudinal seams, and to apply double-riveted welts to steel plates, and to weld up all longitudinal seams of iron plates used in the construction of internal flues. To drill all rivet-holes, without exception, after the plates are bent and put together in their proper position, so as to ensure perfect accuracy of fit for the rivets. To expose no double thickness of plates nor any rivet-heads to the direct action of the flame, and to give considerable elasticity to the entire structure for expansion and contraction with alterations of temperature. To test every boiler with water to a pressure exceeding the working pressure, not in direct proportion to the latter, but to an extent which will ensure a sufficient margin for safety without going to extreme test-loads. To prolong the hydraulic test with variations of pressure for a considerable length of time, during which all leakage is carefully observed and repaired. And, finally, to limit the strain of the extreme test-load to seven tons per square inch on iron, and to thirteen tons per square inch on steel.

The materials used for making boilers at the Newton Moor works are boiler-plates of the well-known brands of iron, and, in preference to these, Bessemer steel plates made at the Bolton forge, or at Messrs. Cammell and Co.'s works. Each plate is ordered from the mill fully two inches longer and wider than wanted for the boiler, so as to give a margin of one inch at each side, which is cut off by a shearing machine, and is made use of for testing the quality of the plate. This plan has the advantage of removing the rough ends of the plates, and at the same time avoiding the use of those portions which are always most likely to contain flaws, impurities, or irregularities for forming the rivet seams of the boiler. The strips removed by the shears, which strips are justly considered to be inferior portions of the plate, are, as we have said, used for testing the quality. Each strip is bent cold by hammering, and is expected to stand doubling up until the ends nearly touch each other, without showi any cracks or fractures, and all plates which fail under this test are rejected. As a rule, the Bessemer steel plates stand more than this, allowing of being doubled up quite close without the slightest signs of fracture. This is due to the precaution of ordering the softest kinds of Bessemer steel plates only, which are never expected to exceed a tensile strength of 38 tons on the square inch, all steel beyond that tenacity having been found too brittle for boiler-making. With boiler-plates, particularly with those of steel, the process of annealing is of the utmost importance. Mr. Adamson has found, by direct experiments, that a plate rolled very hot, and a 'black rolled' plate, will expand at such different rates when heated as to strain the rivet seams; and when tested at the same temperature, the rates of elongation vary so much, that two such plates when joined will never take the strain equally. The process of annealing is, therefore, carried on at the works, and is combined with that of bending the plates. There is, of course, no art in annealing plates, all that is required being care to let them cool as slowly and gradually as possible. After the process of bending, the plates are fitted together by means of a few temporary bolts, which pass through holes previously punched through them. The diameter of these holes is much less than that of the river holes, in order that they may be drilled out to their proper size for riveting after they have served their temporary purpose.

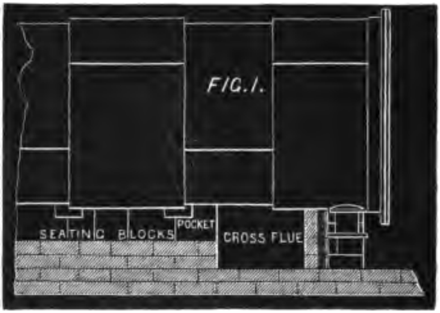
The plates are next put under a drilling frame having six headstocks, with horizontal drills all placed radially, and so arranged as to be adjustable to the diameter of each shell. The holes are drilled with great speed and accuracy, six at a time, and through both superposed plates at the same time. The plates being drilled together never change their relative position, and each rivet is thereby made an absolute mechanical fit. A still more complete machine, having twelve drill headstocks, is now in course of construction at the Newton Moor Works, for their own use; and Mr. Adamson has kindly promised us drawings of this interesting tool for publication. The holes in the flanges and angle irons are drilled in a similar manner by plain vertical drilling machines, all holes being parallel to each other in those parts of a boiler. Riveting is effected by machinery, wherever the shape and position of the parts will allow of the application of the machine. Mr. Adamson considers a machine-riveted seam superior to one made by hand, particularly when steel rivets are used, as with hand riveting, the numerous blows of the hammer cause that degree of brittleness called 'hammer-hardening.' The machines used for riveting at Newton Moor are of Mr. Adamson's own design. They act by raising an adjustable weight through a series of compound levers, this weight actuating the riveting die by its sudden descent. This principle insures the exertion of an exact pressure upon each rivet, and this pressure, whilst it can be adjusted to each kind of work, cannot be altered by the workmen tampering in any way with the action of the machine. For riveting the flanged seams of internal flues a very ingenious arrangement is made use of for withdrawing the back holder by a cam after each stroke, so as to allow another rivet head to pass underneath, and replacing the holder in its position when wanted for holding the rivet head fast whilst the other head is being formed in a manner just described. The longitudinal seams of iron flues are welded up, and the flanges are then bent over a kind of anvil having the corresponding form, by careful hammering at a bare red heat. Steel plates are never welded at Newton Moor, Mr. Adamson considering a weld in steel insufficient in strength to rely upon it for the same strains to which solid steel is considered safe in his boilers. The steel flues have a strip of steel riveted over their longitudinal seam, and this is placed in such a position in the flue as to be but comparatively little acted upon by the flame. The flues are generally made $\frac{3}{8}$ in. thick in iron and $\frac{1}{4}$ in. in steel, the differences in resisting power for different pressures being adjusted by the distance and relative number of the flanged seams. Some of the finest boilers now made by Messrs. Adamson and Co. consist of a steel shell with wrought-iron flues and end plates. The shell and flues are strengthened at their ends with angle-iron rings turned on their faces, same as all the flanges and rings forming the seams. The manholes are welded up from plates, flanged out to shape from the solid, and riveted with drilled holes. At the front ends of the wrought-iron flues, where the grate is situated, it is preferred to substitute steel, which is less liable to blister under the direct action of the flame. The boilers are put together with all joints turned and faced in the lathe, with most rigorous exclusion of all drifts or similar appliances which could cause a strain upon plates or rivets when the boiler is completed. The boiler is then filled with water, and a stand containing two pressure guages side by side, and independent of each other, is screwed upon the manhole.. Water is then slowly pumped into the boiler to a pressure which will cause leakage at any seam or rivet imperfectly closed, and a number of workmen are constantly watching and repairing these leaks. As the pressure is slowly raised, new leaks show themselves, and are repaired in their turn, until a strain considerably above the working pressure is arrived at, and such a freedom from leakage obtained that the pressure gauges will remain almost stationary for several minutes when the pumps are shut off. The pressure is then quickly removed, and after a short time put on again to see if sudden changes will cause any fresh leakage, which would have to be repaired by calking. The final test is carried to a pressure some 50 lb. or 60 lb. above the working pressure of the boiler, and does not bear a strict proportion to the latter. A boiler intended to work at 100 lb. pressure, for instance, is tested to 150 lb. pressure, whilst a boiler for 160 lb. working pressure is tested only to 220 lb. This seems much more reasonable than the practice of testing to double the working pressure, or any other proportionate ratio of the working pressure, which makes the test too light at low, and unreasonably excessive for high working pressures.

The introduction of steel for boiler construction, of which Mr. Adamson has been one of the earliest advocates, is gaining ground very rapidly. The proportion of steel to iron used at the Newton Moor Works has been gradually increasing until the scale has been now turned in favour of the former, and there can be no doubt that steel boilers will come into almost universal use as the safest and most economical in practice. The chief desiderata are now tubular steel plates rolled out of the solid, and seamless rings of angle steel. Designs for a mill for rolling both these articles are now under Mr. Adamson's consideration. Mr. Adamson also intends to plane all straight ends of his boiler plates, so as to improve their appearance and insure a greater facility and regularity in calking their seams."—*Engineering.* The same Journal has the following remarks on

11. *Boiler-setting.*—"The occurrence of another fatal explosion of a boiler resting upon a mid-feather wall has led Mr. Lavington E. Fletcher, in his last monthly report to the Manchester Association for the Prevention of Steam Boiler Explosions, to urge the members of the association to discontinue the use of that dangerous mode of setting, and to adopt side walls with suitable seating-blocks instead. This latter plan is superior on many grounds. If the flues are damp, the moisture rises more readily through the mid-feather than through the side-walls, as there is in most cases less height of brickwork in the former for it to travel through. Also any water that may either fall on to the boiler or leak from the seams is more liable to lodge in contact with the plates on the top of the mid-feather than on the side walls, the bearing surface of the mid-feather being at the bottom of the boiler, so that it collects all the drainage, and being horizontal, so that it retains it, while that of the side walls is inclined, and thus affords the water an opportunity of escaping. It is not thought, however, that the corrosive tendency of moisture is the only cause of the injurious effects of mid-feathers, but that it is materially promoted by mechanical action. A boiler does not "ride" so comfortably on a single longitudinal seating as when carried on two; and when the weight of a large boiler is thrown entirely on a mid-feather, a change of form frequently takes place with every change of pressure. This has been distinctly observed on the application of the hydraulic test, the internal pressure raising the boiler, while it might no doubt be seen in some cases on getting up steam. In making internal examinations of boilers set on mid-feathers, the plates at the bottom of the shell are not unfrequently seen to be flattened all the way along at the centre line, so that the mid-feather can be distinctly traced even inside the boiler. It will thus be seen that an alternate flattening movement is carried on throughout the line of the mid-feather wall on every variation of internal pressure, which tends not only to strain the ring seams of rivets and make them leak, but by its buckling action to "fatigue" the metal, and thus very much to accelerate the ravages of corrosion from moisture upon the body of the plates, so that a mid-feather wall may be said to produce a description of longitudinal "furrowing" along its bearing surface.

Boilers set on mid-feather walls should have the brickwork ploughed out at the transverse seams of rivets for purposes of inspection. Without this it is impossible to ascertain the condition of the plates, since, although they may appear perfectly sound on each side of the mid-feather wall, especially if it be a wide one, may yet be dangerously wasted in a longitudinal "furrow" all along the centre line. These openings need not be large; it will be sufficient if they are about 9 in. long by 3 in. high, and cut completely across the wall, so that if a light be held on one side they can be seen through. They need not be permanently filled up after an inspection, but merely stopped temporarily with a little fire-clay, so as to be easily re-opened whenever re-examination is necessary. The pockets are shown in the annexed sketch, fig. 7.

Fig. 7.



In conclusion, Mr. Fletcher earnestly recommends that no boilers having a diameter of 5 ft. and upwards, should be set on mid-feather walls; but if, in the case of small boilers, and under exceptional circumstances, any of these walls should still be adopted, then the boilers should rest on suitable seating-blocks instead of on bricks; while the bearing surface should not exceed an inch in width for every foot in the diameter of the boiler, and sight-holes, as explained above, should be ploughed out at each of the ring seams of rivets."—*Engineering.*

12. *Principles involved in the designing of Vessels for generation of Steam.*—From the introductory portion of Mr. V. Pen-

dred's paper on Water Tube Boilers, more than once already quoted from, we take the following on this important subject:—"We must first determine exactly what it is we want to do, and this settled, how it can be done best; how we actually propose to do it, and how far our proposed arrangements are the best. In order to make steam we have only to boil water, and, therefore, speaking at large, when we wish to make steam we have only to place water in a vessel and heat it, and the thing is done. But the trained engineer knows that the formation of steam stands at one end of a succession of events of the most important and interesting character, commencing *in limine* with the oxidation of fuel; and he further knows that the relations which those events bear to each other are so complex, the forces of nature called into play at once so powerful and so subtle, that the generation of steam, whether in a test tube over a spirit lamp, or in the boilers of a mail steamer, presents for his consideration some of the most interesting problems which can be brought before him. The comprehension of the phenomena of the combustion of fuel, the liberation and absorption of heat; the laws of radiation, conduction, convection, &c., is absolutely essential to the preparation of a good design for a steam boiler of any kind; and the author proposes to show that the water tube boiler, better than any other, can be made to comply with laws the rigid observance of which can alone secure a maximum economic efficiency without the sacrifice of rotential efficiency.

The process by which power is obtained in practice from the combustion of fuel may be divided into two distinct departments, which, although habitually and very intimately connected in the minds of men familiar with steam machinery, really have but a remote and arbitrary connection with each other. The first embraces all that concerns the manufacture of steam; under the second is included all that concerns the use of steam after it is made—a subject with which this paper has nothing whatever to do. The manufacture of steam—in which it is wished to include not only the phenomena going on within the boiler, but those manifested outside, in its furnaces and flues as well—may be again divided into two departments, under the first of which rank all the phenomena connected with the production of heat by combustion, and under the second those connected with the cor duction of heat by metals, its transmission by gases, and its absorption by water and steam. With the first of these subsidiary heads this paper has very little to do; the questions connected with combustion alone would deserve a paper to themselves, and have already been fully discussed before this society. In so far as combustion is influenced or affected by a particular form of boiler or system of generating steam, its theory and practice will be touched upon, that is all. The phenomena of the absorption, &c., of heat, and the influence exerted by their laws on the form which should be imparted to a steam boiler, claim much more attention at present, as being intimately connected with the matter in hand.

The idea of using small tubes as steam generators is very old, and in all probability took its origin from the fact that it was quite impossible to obtain in the infancy of the steam engine vessels of much individual capacity which would be strong enough to withstand high-pressure steam. The first steam engine ever made which performed useful work was Captain Savery's, and it was unquestionably actuated by high-pressure steam. Savery, indeed, burst his boilers so frequently that his invention was disgraced. After him came Newcomen, then Smeaton, and finally Watt, all three apostles of low-pressure. But there were not wanting men living in the latter half of the last and the beginning of the present century who advocated high-pressure quite as energetically. It was vain to urge the use of high steam without explaining the means by which it was to be generated. The most eminent of the representatives of the high-pressure system were Oliver Evans in America, and Woolfe, Perkins, and Trevithick in this country. Woolfe, Evans, and Perkins, all produced ingeniously constructed boilers, in which the water was enclosed in small tubes and heated from the outside. After them came James, Handcock, Gurney, Dance, Ogle, &c., and, in short, nearly every one who has attempted to run steam omnibuses on common roads. It is impossible to examine drawings of these steam carriages without perceiving that the heating surface allowed was usually so small, and the general capacity of the boilers so insignificant for the work they were expected to perform, that only disappointment could result from their use. It is not to be argued, however, from this fact, that the principles of boiler construction were wholly misunderstood. On the contrary, the subject was fairly enough comprehended by Evans and several others, and the explanation of the bad proportions of the road locomotive boilers can easily be found in the desire to keep down size and weight displayed by their contrivers. Among all those who laboured to produce a good water-tube boiler the author is at a loss to single out one who undertook the task with a more thorough appreciation of the difficulties which lay in his way, and displayed more ingenuity in the attempt to overcome them, than Dr. Ernst Alban, a mechanical engineer residing at Plau, in Saxony. There is a remarkable dearth of literature concerning boilers, and Dr. Alban is one of the few who have written treatises on the subject. He has so fully pointed out the qualifications which a good boiler should possess that this treatise, although penned more than twenty years ago, may still be read with profit, embodying, as it does, the results of a life-long experience in dealing with steam of pressures varying from 100 lb. to 1,000 lb. per square inch; and the writer feels that in that which immediately follows, he has hardly been able to add a single new remark to, or strike out one rendered obsolete by the progress of science from Dr. Alban's chapter on boilers for high-pressure engines.

Water-tube boilers may be divided into distinct classes, the characteristics of which will be defined presently. Before coming to their particular consideration it will be well to lay down the conditions which must be complied with in any design claiming to be considered good. Alban lays down the following rules:—'1st, The tubes must be placed in such a position in the furnace that the flame may act upon them in the most favourable manner, and that the heat may be absorbed as completely as possible; 2d, they must have such a proportion between their length and diameter that neither ebullition in them may become too violent, and the water be thereby ejected from them, nor that they be warped and crookened by the heat; 3d, they must properly convey away all the generated steam and be regularly supplied with water; 4th, they must be so deep under the general level of the water in the boiler that some considerable sinking of the water level may take place without leaving any of them empty; 5th, they must be so connected together that no destructive expansion may be allowed to take place, and that all may be easily cleansed of deposit.' Dr. Alban adds another condition very difficult of fulfilment, which, however, is given here, although the author does not wish to endorse it in the fullest sense: '6th, the tubes must be connected to the main part of the boiler in such a manner that in case of a rupture occurring in one of them the whole content of water and steam may not be able to rush out and discharge itself suddenly and dangerously.' It is believed that although this object can easily be attained to a great extent, its full realization can only be had by running the risk of suffering the communication with the tubes to be altogether stopped up.

As the foregoing rules stand no one can for one moment dispute their soundness, and it will be generally admitted that any generator, in the construction of which they were fully observed, should prove thoroughly excellent, ebullition would proceed gently, therefore dry steam would be supplied to the engine; the flow of water would be regular, therefore overheating would be impossible; the heat would be absorbed completely, therefore none would be wasted. Let us now proceed to consider in what manner those rules may be best applied in practice.* The first point for consideration is the disposition of the tubes with regard to the furnace. Until this is settled it is not easy to determine the number which should be adopted for a given power, or their diameter or length.

In approaching this branch of the subject it is well to bear in mind that each tube should be regarded as a little boiler, distinct and complete in itself, within which there must be perforce a steam space as well as a water space, and that all these little boilers require to be connected into one system; and as it would not be convenient for the engine to draw directly by a distinct steam pipe from each tube, they must all deliver their contributions of steam into a reservoir common to them all; and as it would be equally inconvenient to supply each with water by a distinct feed pump, they must all draw their feed water from a common reservoir or source of supply.

There are but three positions which the tubes of a water-tube boiler can assume: they may be horizontal, vertical, or inclined.

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* Arrived at this point, the writer can no longer accept Dr. Alban as the best guide. The method in which he carried out his views is illustrated in the diagrams, and will be referred to more particularly hereafter.

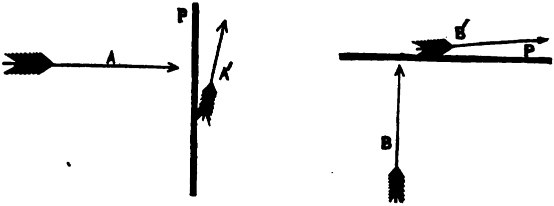
All these have been adopted. It remains to be decided which is the best, and this point will be determined mainly by two considerations. The first is, 'that the flame or the heated products of combustion may be made to act on the tube in the most favourable manner;' the second is the system of circulation adopted; and these two questions are intimately connected, in so far as it happens that the means employed to secure circulation may render it impossible to obtain the full heating value from the flame; while, on the other hand, many boilers in which the tubes are arranged in the best possible manner for taking up the heat, have failed because the means of obtaining an efficient circulation within the boiler have not received due attention. As these two questions are the most important of all the problems connected not only with tubulous boilers but with boilers in general, they will be considered at some length, and, for convenience, as distinctly as is compatible with the intimate connection which exists between them.

When water is heated as in a steam generator, a plate of metal invariably intervenes between the gases from which heat is to be abstracted and the water which is meant to absorb it. Through this metal the heat must pass by conduction, and a little examination will show that the process of imparting caloric to a body of water may be divided into three distinct operations; the first is the communication of heat to the outer surface of the plate; the second is the conveyance of heat through the plate; and the third is the absorption of heat from the inner side of the plate by the water or steam in contact with it.

In considering these questions the author proposes to avoid theory as much as possible. He will not hypothecate a laboratory experiment, but knowing that his hearers are too well versed in science to require elementary information he will draw a comparison between what takes place in an ordinary Cornish boiler and in a water-tube boiler.

In the Cornish boiler we find that the flame traverses the flues in a line parallel to the plate, which is practically the worst possible direction flame could take. It may be laid down as an axiom that the plate to be heated should always be placed at right angles to the current of flame, and the direction of the water current should, without being actually parallel with the plate, still depart from it at a very slight angle. Thus, let P, P, Fig. 8, be two plates, the one vertical, the other horizontal, then the best direction for the flame currents will be either in the direction A

Fig. 8.

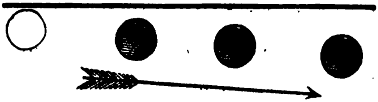


or B, while, for reasons to be afterwards explained, the water currents should move in the direction A¹, B¹. In considering the questions connected with the influence of direction as referred to the plate, on the efficiency of the flame current, it may be observed that the question has not received the full attention it really deserves from English writers, if, perhaps, we except the late Mr. Wye Williams, who, a short time before his death, published a pamphlet on the value of tube plate surface, which contained some truths, and a great deal of theory and false reasoning not justified by experiment. The best authority, as far as the author is aware, on the subject is M. Peclet, a French *savant*, whose talents have obtained for him a very considerable reputation. His remarks on the action of flame in the flue of a boiler are so pertinent that they are reproduced nearly as they stand.

'Speaking now of the heating of liquids by a gas, as, for example, in the case of a steam boiler, and of that portion which does not receive the direct rays of heat radiated from the fuel on the grate,' that is to say in the flues, 'the quantity of heat which traverses the plate is invariably determined by the difference in temperature on its opposite sides; the absorbing and emissive powers of the two surfaces of the plate, *and above all by the movements of the sheets* (*lames*) *of gas which are in contact with the metal.* It will be found in all cases that the rapid renewal of layers (*couches*) of liquid or gas which touch the surfaces of the metal plate has a very great influence upon the transmission of heat, but this circumstance is *much more important in the case of gases than in the case of liquids.* We should therefore endeavour to obtain that arrangement of the apparatus which is most favourable to this rapid renewal.' After referring to the propriety of providing an artificial gas circulation, M. Peclet continues:—'Considering, for example, that the products of combustion escape at a high temperature into a circular flue surrounded with water which we wish to heat, the sheets of gas which are in contact with the plate are cooled down with great rapidity. But all the little elementary currents having a direction parallel with the axis of the flue, the sheets of gas change places very slowly; because the only cause for change lies in the acquisition of density which results from cooling, but this change of temperature only takes place in the upper portion of the flue, and it tends to produce displacement with but a slow speed. It follows, therefore, that if the section of a flue be very considerable, and the speed at which the gases move through it be high, the greater part of the central veins will not come in contact with the surface of the plate, and they will therefore preserve their original temperature.' M. Peclet then proceeds to suggest the use of small paddle-wheels placed in the flue, and caused to rotate by the current, much like a smoke-jack. These, by their rotation, would break up the current and project the products of combustion against the sides of the flue. It is unnecessary to consider this scheme at length, it would probably answer its purpose, but the same object can be more effectually carried out by other means.

In order to illustrate M. Peclet's reasoning the annexed diagram has been prepared. In it the top plate of the flue of a

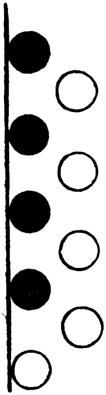
Fig. 9.



Cornish boiler is represented by the black horizontal line; under this are seen a number of circles representing atoms of gas. At first these are of a brilliant red, denoting high temperature; as they move along the flue, however, they cool down, and sinking, give place to others; but the difference in density is small, and, consequently, the tendency to sink; so that they are carried nearly to the end of the flue before they can get fairly away from the plate; and it is highly probable, if not certain, that they are supported and buoyed up by the rapid motion of the current on which they partially float, much on the same principle that a stone is supported for a time when thrown into a current. There can be no doubt but that, in the single-flued Cornish boiler especially, the central portion of the great body of heated gas moving from the furnace reaches the end of the boiler without any sensible reduction of temperature, but being broken up or mixed by the angles or bends diverting it into the side flues, the gases then give up much heat which, but for the breaking up of the column, would escape into the chimney.

M. Peclet's reasoning explains very clearly how it is that flame operates to a great disadvantage when traversing a horizontal flue in a direction parallel with its axis. When we come to deal with vertical flues the case is much worse. In fig. 10 it will be seen that the balls ascend along the plate until they lose their heat, and as specific gravity cannot affect their position, they continue to remain in contact with the plate long after they are cooled, the central portion of the column of heated air not coming in contact with the sides of the flue at all.*

Fig. 10.



Let us now compare this with the action of a current of heated gas impinging on a plate at right angles to its surface, a construction which may be easily secured in all water tube boilers, though it is incompatible with the Cornish boiler. Here each portion of the gas is driven away the moment it is cooled by the next succeeding portion, or before it is cooled if the velocity of the current is high. No one set of particles, or, in other words, sheets of gas, can remain in contact with the surface of the plate to the exclusion of another and hotter set, and therefore the heat of the current must be abstracted as fully as possible. In diagram, fig. 11, we have the action of the gas atoms illustrated. For convenience they are represented as balls dropping from a height on a succession of plates, but it is of course obvious that were the diagram turned upside down or on its side the action would not be affected. The balls scattering, so to speak, over the plates, part with their heat; those which have not the opportunity of giving it up completely to the surface with which they first come in contact yield up to the next or to some succeeding plate, until the whole is absorbed. It will be shown presently how this principle, theoretically and practically the best on which heating surface can be arranged, may be carried out in practice. It is well to remark here, that not only is a direct advantage to be gained by the additional surface obtained by multiplying the number of plates exposed to the action of the current, but that any expedient which tends to mix the volume of gas and to render its temperature uniform throughout, must be useful, because such a mixture renders it impossible that any one portion of the products of combustion should fall to the temperature of the heated water, while other portions retain a high

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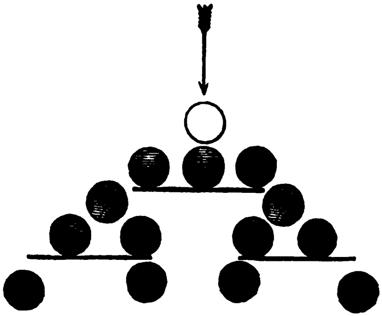
* Boilers with small vertical fire-tubes have proved tolerably efficient, but this is solely in consequence of the fine division of the products of combustion effected by passing them through very small tubes. The efficiency of not only vertical but horizontal fire-tube boilers would be much less than it is were it not that a certain whirling motion probably takes place within the tubes, which tends to bring fresh portions of gas against the metal.

Fig. 11.



temperature. That portion which is cooled by coming in contact with the plate is heated again by being mixed with others of a higher temperature, and is therefore in a condition once more to act on the surfaces with an efficiency, less, indeed, than that which it originally possessed, but much greater than it would have displayed had it remained in the thermal condition in which it first left the plate."

SECTION SECOND.—BOILER APPLIANCES AND MANAGEMENT.

14. *Novel Invention to Prevent Incrustation of Boilers.*—At one of the stands in the galleries of the Smithfield Show in December of last year—that of Mr. Nicholson, of Newark-upon-Trent—there were to be seen, occupying anything but an obtrusive place, one or two specimens of a material, or, to put it properly, materials, which are not to be met with every day, but which carried with them very much that was suggestive, and suggestive, too, of very important interests. These materials presented the appearance of thin, flat, irregular shaped pieces of what at first sight might be taken for rather thickish scales—so to speak—of shale or stone, but which, on being handled, presented in some respects the appearance of metal, in others that of lime extremely hardened. These were neither more nor less than portions of 'scale' which had been taken from the interior of boilers, formed through that bane of boiler-working, 'incrustation,' and which arises from deposits formed in the water which supplies them. So far as the appearance of these scales presented, there was nothing very remarkable, unless the extreme solidity and closeness of the texture could be—as, indeed, it might justly be—named remarkable, but the same could scarcely be said of the way in which these scales had been obtained. Many of our readers doubtless know what is conveyed in the term 'incrustation of boilers'—the loss of fuel and damage to the plates, and the risk of explosion and loss consequent therefrom—and they know also of the numerous schemes which have been promulgated for its prevention, and the still more numerous schemes brought forward for its cure. To many the term conveys no other idea but that of inconvenience of a certain character not deemed likely to be serious further than that it may cause an extra expenditure

of fuel—no great matter to many in these days of cheap fuel, who care nothing for speculation as to the time when it will not be cheap—but this restricted view of incrustation is by no means a correct one; we have no hesitation, indeed, to say that through incrustation many most serious explosions have taken place, and the risk of many more taking place in future daily incurred. The scale covers the plates, causes them to be overheated, and, from the unequal expansion and contraction to which they are subjected from its presence, the wear and tear of the boiler is much increased; it prevents proper examination of the plates so as to ascertain their condition, and frequently corrosion goes under it, and proceeds to a highly dangerous extent, and yet its existence is not known, or, if conjectured, cannot be properly ascertained till all the scale is taken off, a matter which involves more trouble and expense than is sometimes thought of, in some cases the scale being so welded, so to speak, to the surface of the plates that even with the aid of the hammer and chisel the greatest difficulty is experienced in getting it off. Further—and, for the present, finally—water which causes incrustation in the boiler also causes certain wear and tear of the working parts of the steam-engine which it works, the earthy matter in it being frequently carried over by the steam, especially where the boiler is 'priming'—that is, carrying over steam saturated, or partly so, with water—and getting fixed in the valve faces and inside of cylinder and working parts.

We have said enough, then, to show the very great drawbacks which arise from the incrustation of boilers, and the importance of any mode by which it can be prevented. The most obvious way is, of course, to use good water. This does not imply that the water is good because it may happen to be pure and clean; for what might, compared with a pure water, be called almost a dirty one, may, and often does, yield less deposit. The carbonate of lime, if present in water, yields a soft deposit or loose powder, which may be, and in practice is, got rid of by the process of 'blowing out,'—that is, allowing a certain quantity of the contents of the boiler to be blown out of or through a cock and pipe properly placed in the boiler for that purpose. If the water contains a sulphate of lime, the deposit is formed as a hard crust cake or scale, and if both the carbonate and the sulphate of lime are present in the water used for boiler purposes, then a crust is formed more or less dense or hard in proportion to the per-centage of the carbonate or the sulphate present. It is not always, indeed not often, that a choice of waters is presented to the users of steam-power, but where it is, it is assuredly the wisest plan to have them analyzed, so that the best amongst them may be taken. But where one kind of water only is available, and that kind

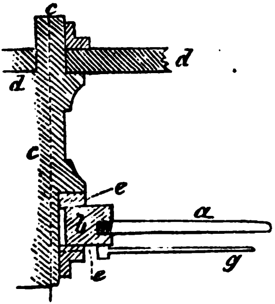


Fig. 12.

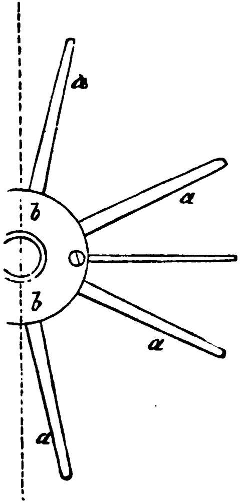
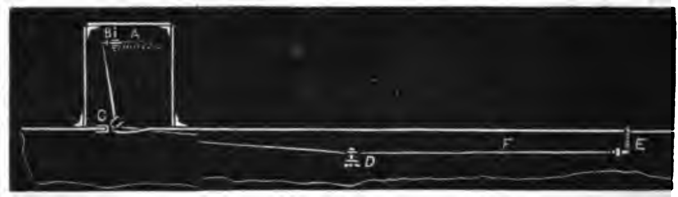


Fig. 13.

bad, the next plan to the users of steam-power is to employ a mode of preventing the scale or deposit; and here the difficulty comes into play, how to choose amongst so many plans. As already hinted at, these are exceedingly numerous; and so few out of the many are thoroughly good, that it is not the embarrassment of riches, as the French say, but that of poverty, which is the puzzle to those who are choosing. This brings us to the more immediate subject of our note, the description of the method of preventing incrustation alluded to at the beginning of this paper, which, if it proves to be as efficient as it is startlingly novel, will prove not only the fortune of those concerned in its manufacture, but the henceforth ease of mind of conscientious boiler-men. When we name it as the *magnetic* anti-incrustator, we suspect that it will bring to mind sundry notions, such as magnetic hair-brushes and the like, more suggestive of humbug than of honesty. But it is ever dangerous to judge of a thing from first appearances, and if all we have heard of this invention comes up to only a tithe of its practical importance, the same may hold true of the invention at present under notice; and it is right to state at once, that those who have tried it, and speak favourably —highly—of it, are amongst the first, if not the first, of our practical men. We have perused the letter of a high authority, who gives a most favourable notice of it, yet who frankly stated that he allowed it to be fitted up in his boiler in the notion that the trial would be an utter failure. In America, where the invention was first brought out, its success has, according to one statement, been very marked. The professional journal, 'Engineering,' in the issue of a fortnight ago, stated that it is now being tried in a case well adapted to give it a fair trial, and of that trial progress will shortly be reported. The instrument, shown in part section in fig. 12 and in plan fig. 13, consists of seven small magnets of steel wire about 3½ inches in length and some ¼ inch in diameter; these are screwed radially into a brass or gun metal centre *b;* this is supported by a brass stud *c c*, which is connected to the top boiler plate *d d*. The stud is insulated by the intervention of India-rubber washers *e e*, and a porcelain bush *f f*. A small copper wire—diameter No. 11 wire gauge—*g* is connected to the centre *b*, and at the other end to the end of the boiler. The system of magnets *a a* being thus connected with the boiler, 'a current of induced electricity is thus conducted from the magnets at one end of the boiler to the shell of the boiler at the other, and by the shell itself back to complete the circle.' The magnets are suspended in the steam space, a few inches below the roof of the boiler *d d.* We have seen no explanation of the peculiar influence this instrument exerts upon the boiler plates and the matter which is or would be deposited in them, but, according to the inventor, its action is not only remarkable in preventing, in cases of clean boilers, any deposit, however bad the quality of the water, but it is equally remarkable in clearing thick scales from boiler plates already thickly encrusted with it. (Those scales we saw at the Smithfield Show, and to which we have already alluded, were taken off by its means.) This would seem to point to some peculiar vibratory action induced in the plates, by which alternate contraction and expansion is induced, thus preventing the deposit, and, where deposit is made, causing it to peel or crack off somewhat after the manner in which Harrison's cast-iron sphere boiler (described in a previous vol. of "Engineering Facts and Figures") prevents deposit from the alternate contraction and expansion of the spheres of which it is made up.

Since the above was written, the following paper in "Engineering" under date August 30th, 1867, has appeared. We give one only of the illustrations of this article, referring the reader to the pages of "Engineering" for the remaining six diagrams:—

Fig. 14.



"It is now more than eight months since we published in this journal a letter from Mr. Hoadley, of Lawrence, U.S., in which he gave an account of a 'magnetic anti-incrustator' which was being used in America, with considerable success, for removing the scale from steam-boilers. The results mentioned in this letter attracted considerable attention, and they led Mr. George Livesey, of the South Metropolitan Gasworks, to have an instrument constructed from the description given by Mr. Hoadley, and to apply it to one of the boilers under his charge. Of the instrument constructed for Mr. Livesey we gave an illustration and description on page 24 of our third volume. The result of this publication was a letter from Mr. Baker, stating that he held the English patent for the anti-incrustator, and that the instrument had been for some months at work on boilers at Messrs. Maudslay, Sons, and Field's, the Monkbridge Ironworks, and some other places. More recently, the manufacture of the 'anti-incrustators' has been taken up on an extensive scale by Messrs. Kitson and Co., of the Airedale Foundry, Leeds; and many improvements having been made in their construction, we propose giving a description of them in their present form.

In the annexed engravings, A represents the 'battery,' as it is now called, which forms the main portion of the arrangement. It consists of a brass casting having inserted in it radially a number of steel magnets sharply pointed at the outer ends, as shown. The brass of which the casting is made contains a large proportion of copper, and the stem of the 'battery' can thus be readily bent by hand, to suit it to various positions in a boiler. In the earlier instruments, the points of the magnets were protected by silvering them; but it was found that the water used in some boilers caused the rapid oxidation of the silver coating, and that the coating of oxide so formed, in a few instances, prevented the instruments from working properly. To avoid this, Messrs. Kitson now coat the magnets with copper, then silver them, and, finally, electro-gild them, this coating of gold effectually preventing any failure from the cause above mentioned.

The 'battery' above described is so fixed in the boiler that it is fully exposed to the current of issuing steam on its way to the steam-chest. At first the instrument used to be fixed with the points of the magnets inclined downwards, but it was found that when so fixed there was a tendency for a deposit to be formed on the points of the magnets—any water carried up by the steam, and arrested by the anti-incrustator, draining down to these points and then dropping off—and the instruments are accordingly now fixed with the points sloping upwards.

The battery is supported by the insulating stud B, this stud being formed as follows: the stud itself, which is screwed into the top of the steam dome, or any other convenient part of the boiler, is of brass, and it has a collar formed on it as shown in the engraving. Against this collar is placed a washer of India-rubber, and next this a pair of porcelain insulators with an India-rubber washer between them. Above the insulator is another India-rubber washer, and finally the brass washer and nut by which the insulators are secured. It will be seen from the engravings that the porcelain insulators are furnished with collars, between which the neck of the instrument is securely held, and they have also formed on them small projections, which fit into a groove on one side of the eye of the stem of the 'battery,' and thus prevent the latter from shifting round. The insulators are themselves prevented from turning on the supporting stud by that portion of the latter which passes through them being made square.

The 'battery,' being thus insulated from the parts of the boiler in its immediate neighbourhood, is connected with some distant point by a stout copper wire, this wire leading from the end of the stem of the 'battery' to a contact stud, E, screwed into the boiler at some convenient point, as shown in the sketch, representing the general arrangement of the apparatus. The wire is secured to the contact stud by inserting it into a hole formed in the end of the latter, this end being split and being provided with a tapered screw on the outside, so that by tightening up a nut placed on it the wire can be securely held. The same means are employed for connecting the wire to the stem of the battery. Where the wire is led round the corner formed by the junction of the dome and boiler, it is led through an insulator carried by a bracket, which clips the edge of the edge of the boiler-plate, a bracket of the kind being shown in the engravings at C. An insulating bracket, of the form shown at D, is also used in long boilers for supporting the wire where necessary. In the case of locomotive boilers a different form of contact stud to that above described has to be employed. In such the boiler's wire is soldered into the end of the contact stud, which is made straight, and is screwed in through the backplate of the firebox casing, the wire having been first inserted. The other end having been connected to the battery, the wire is drawn tight by screwing back the contact stud. In all cases the contact stud must be screwed into the plates dry, so that a perfect metallic contact may be secured between it and the boiler. It is also necessary that any boiler to which the anti-incrustator is applied should not be connected metallically—as by steam-pipes, &c.—with any other boilers, unless these are also provided with the apparatus. If this fact is neglected, the action of the instrument will be distributed over the whole of the boilers, and no really effective result produced on any of them.

Respecting the manner in which the anti-incrustator acts in removing the scale from a boiler we shall not say much here, and, in fact, no thoroughly satisfactory explanation of its action has yet been advanced. In fact, doubts have from time to time been expressed whether it produced any electric current at all; but recent experiments made by Messrs. Kitson at their works show decisively that an electric current does exist when the apparatus is in use. In the experiments referred to, the boiler to which the apparatus was applied was filled with water, so that the instrument was completely immersed, and the fire was then lit. The wire connecting the battery with the contact stud had been led, before being connected to the latter, through an insulated stuffing-box fixed on the front of the boiler, and a galvanometer having been placed in the circuit, any currents that passed through the wire could be observed. When water became thoroughly heated the galvanometer was deflected 4°; and when steam was got up and the water partly boiled off, so that the instrument was situated just above the water-line, this deflection rose to 11°. Finally, when the water-level became still lower, and the battery became exposed to the full current of dry steam on its way to the boiler, a deflection of 14° was obtained.

Whatever doubts may be expressed as to the manner in which the anti-incrustator prevents the formation of scale and effects its removal, if already formed, there can be no doubt but that it does do these things. There are now some hundreds of the anti-incrustators at work both in this country and in America, and, except in those few cases already referred to, where, from defective construction, they failed from the formation of a non-conducting coating on the points of the 'battery,' they have given excellent results, scale already formed being caused to fall off in fragments, and the impurities of the water being deposited as a soft mud easily removable by the process of blowing off. Considering the trouble which is so frequently occasioned by the presence of scale in a boiler, and the expense and difficulty attending its removal by ordinary methods, it seems probable that an instrument which obviates these annoyances as completely as the anti-incrustator does will some day become as universal as a boiler-fitting as a gauge-glass or blow-off cock."

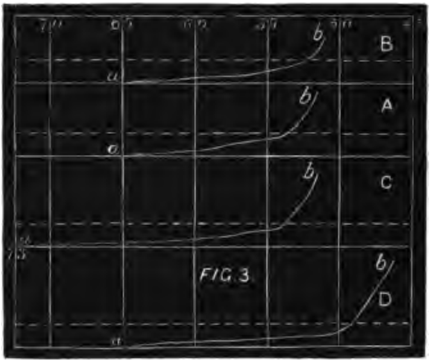
The opinion of the "Scientific American," compared with the above, on the subject of electrical anti-incrustators, may, curiously enough, be suggestive here. "We observe that the 'Railway Times' gives prominence in two successive numbers to remarks before the Polytechnic Institute on a new remedy for boiler incrustation, as reported in this paper. We do not object to seeing our report credited to another journal, if it is ot be construed as countenancing the slender theory there explained as the basis of another patent electrical anti-incrustator. As a company is said to be forming to manufacture apparatus under the patent, and quite possibly may get as much commercial success at the expense of boiler owners as the not much more meritorious contrivances already in the field have met with, a word on the fallacy involved may be opportune for some of our readers.

The inventor bases his expedient on the existence of a positive electrical state in the suspended salts carried up into the steam space. It need not be denied that the low conductivity of steam favours a sustained slight disturbance of electrical equilibrium during its rapid disengagement. But it is needless, too, to point out that uninsulated bodies in connection, like the boiler and its contents, whatever they may be, cannot sustain an active electrical state of any practical consequence. The most they could do in the circumstances would be to supply an indication through a delicate galvanometer. The proposal, therefore, to collect this trivial amount of electric force upon metallic points and convey it to the boiler iron so as to obtain a discharge between the iron and the salts which was not attained before by the free contact of the two, is refinedly visionary. The Doctor should never say a word against homœopathy. As for deposits enveloped within so good a conductor as water, the notion of employing their electrical activity has not even a theoretical basis."

15. *Safety Valves.*—(*a*) The following paper was read before the "Society of Engineers" by Mr. Thomas Baldwin, under the title of "Experimental Researches into the Nature and Action of Safety-valves for Steam Boilers, &c."—"It often happens that a safety-valve is weighted to within a few pounds of the maximum pressure that a common open mercurial steam-gauge will indicate, and it frequently happens that when no steam is taken from the boiler, or the boiler has an excess of capacity over the work it has to do, that the pressure will rise in spite of the safety-valve and blow out the mercury of the steam-gauge, in which case the safety-valve does not answer the purpose intended, as it allows the steam to rise to a higher pressure than it ought to do. This state of things having come under the author's personal observation, it was determined, in the year 1857, to make experiments to ascertain to what extent the pressure in a steam boiler might exceed the calculated pressure on the safety-valve without the safety-valve being sufficient to carry off the steam generated in the boiler. For this purpose a small valve, 1 in. in diameter, having a lever and weight, and of the ordinary construction, was fixed on the top of a 1 in. pipe, 12 in. long, inserted in the manhole cover of a common two-flued Lancashire boiler, belonging to Mr. Daniel Smith, of Bury, Lancashire. The lever of the valve was 14 in. long, and the distance from the centre of the valve to the fulcrum was 2 in., the moveable weight being 6·09 lb., and the weight of the lever and valve was taken and allowed for in all the experiments. The lift of the valve was ascertained by placing a brass plate close to the end of the lever, and during the time the steam was flowing from the boiler at each definite lift a mark was made on the plate by a fine steel marker. A pair of fine-pointed compasses were used to measure these lifts, and each lift pitched fifty times along a straight line on a brass plate, and the length measured and divided by fifty to insure accuracy in the measurement of the lift. The pressure was also noted during the time of flow.

Experiments.—The curve line *a b*, fig. A, shows the height the valve lifted from its seat as the weight in pounds per square inch was taken off the valve. The vertical lines divide the figures into pounds per square inch, and the vertical scale is one-seventh of the horizontal one. The distance the valve opens is exhibited

Fig. 15.



by the distance, measured vertically, from the straight line, *a c*, to the curved line, *a b*. At *a* the valve is closed, and the pressure in the boiler is 65 lb. per square inch, including the atmosphere. The dotted line passing across the figure shows the position of the valve when lifted one-twentieth of an inch, which would take place when the weight on the valve is equal to about 53⅜ lb. per square inch. The pressure in the boiler began to increase at *d*, which is the cause of the curve of contrary flexure at that point. The valve used in the experiment connected with fig. A was a disc of 1¼ in. diameter, guided by pins on the outside.

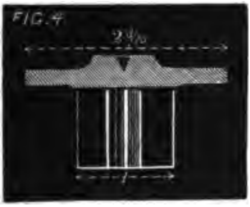
Fig. B shows a diagram constructed from another experiment with the same valve, and at the same pressure as before; but in this case the pressure did not vary in the boiler during the experiment. The curve, *a b*, is an hyperbola with one asymptote very close to the line *a c*, and the other at about 48° from the line of pressure, *a c*. The valve is open $\frac{1}{20}$ of an inch at about 53¼ lb. on the diagram; or, in other words, the weight on the valve was 53¼ lb. when steam in the boiler at 65 lb. did not lift the valve more than $\frac{1}{20}$ of an inch from its seat, the steam from the boiler issuing into the atmosphere.

Fig. C (in fig. 15) shows an experiment with a disc valve $1\frac{1}{4}$ in. diameter, with three thin wings passing into the interior of the valve-seat to guide the valve, the pressure in the boiler being 73 lb. Although we have a pressure of 73 lb. in the boiler, the valve does not lift $\frac{1}{20}$ in. until the weight upon it is reduced to 54 lb. per square inch. This is probably owing to the exit of the steam, being retarded by the wings of the valve, reducing the area of the passage into the atmosphere. By weighting the valve to $52\frac{3}{4}$ lb. per square inch, we find, although the pressure on the valve has only been reduced $1\frac{1}{4}$ lb. per square inch, it is now open $\frac{1}{10}$ in. Down to a pressure of 56 lb. the lift of the valve increases nearly constant with the decrease of pressure on the valve.

Fig. D is another experiment with the same valve, the pressure in the boiler being 65 lb. In this case the valve is lifted $\frac{1}{20}$ in. when the pressure on the valve is reduced to $49\frac{1}{4}$ lb. per square inch.

Fig. E (in fig. 17) shows a diagram constructed from an experiment with a valve the disc of which is $2\frac{5}{10}$ in. diameter, the valve face being $\frac{1}{8}$ in. broad, and the remaining portion sunk about $\frac{1}{20}$ in. to allow the steam more room to pass—as in the figure below,

Fig. 16.



showing a section of the disc. The pressure in the boiler was 67 lb., and the valve lifted $\frac{1}{20}$ in. when the pressure on the valve was reduced to $48\frac{3}{4}$ lb.

Fig. F shows a diagram constructed from another experiment with the same valve, the pressure in the boiler being 70 lb. per square inch. The valve opens $\frac{1}{20}$ in. when the pressure upon it is reduced to 50 lb. per square inch.

Fig. 17.

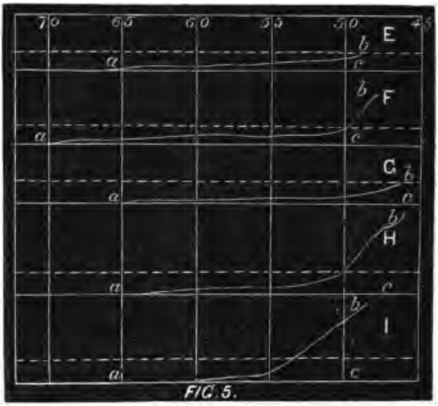


Fig. G shows a diagram constructed from an experiment with the same valve, the pressure in the boiler being 65 lb., and shows the valve to be open $\frac{1}{20}$ in. when the pressure on it has been reduced to 45½ lb. per square inch.

The curves of the last three experiments agree very well with each other as to being of the same kind of curve.

Fig. H shows a diagram constructed from an experiment made with the same valve as that used for figs. C and D, with three wings, the disc being reduced from 1¼ in. to 1⅛ in. diameter. The pressure in the boiler was 65 lb. per square inch. The valve lifted $\frac{1}{20}$ in. when the pressure on it was reduced to 51 lb. per square inch.

Fig. I (in fig. 18) shows another experiment with the same valve, and at the same pressure of 65 lb. in the boiler. The valve lifted $\frac{1}{20}$ in. when the weight upon it was reduced to 52½ lb. per square inch. The curves in the last two experiments differ from each other, which is probably caused by the flow of steam to other places, the boiler being used for driving a steam-engine and for boiling purposes at the time of this experiment.

Fig. J is another experiment with the same valve as used in the experiments E, F, G, but carried to a further extent in opening the valve. The valve opens $\frac{1}{20}$ in. when the pressure on the valve is reduced to 48 lb., the pressure in the boiler being 65 lb. per square inch.

Fig. 18.

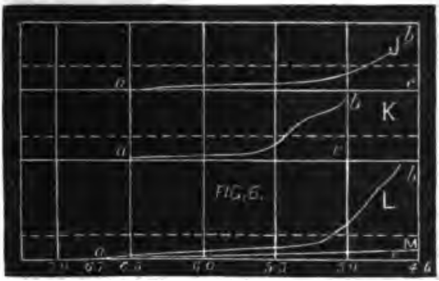


Fig. K was constructed from an experiment with the same valve as used for H and I, with this difference, that the spaces between the wings were filled up with Roman cement until the filling in formed a parabolide 1 in. diameter at the base and 1 in. high from base to apex. The valve was found at the close of the experiment to have lost all the cement, which will account for the irregular shape of the curve. The pressure in the boiler was 65 lb. per square inch, and the valve opened $\frac{1}{20}$ in. when the weight upon it was reduced to $54\frac{1}{3}$ lb. on the square inch.

Fig. L shows a diagram constructed from an experiment made with an *ordinary valve* with three wings and conical face, the angle of the slant side being 45° and breadth of face $\frac{1}{8}$ in., the diameter of the inside of the valve as before. The pressure in the boiler for this experiment was 67 lb., and the valve lifted $\frac{1}{20}$ in. when the pressure on the valve was reduced to $51\frac{3}{4}$ lb. per square inch.

Fig. M is constructed from an experiment made with the same valve as used for figs. E, F, G, and J, with this difference, that the face of the valve was $1\frac{1}{8}$ in. diameter, and the outer portion of the disc very nearly touched the flat portion of the seating—it was not more than $\frac{1}{100}$ in. from touching. The pressure in the boiler was 67 lb. per square inch, and the valve only lifted $\frac{1}{80}$ in. when the weight upon it was reduced to 45 lb. per square inch. This experiment shows that broad faces for valves ought not to be used; for a reduction of the weight on the valve to 45 lb. per square inch only allows the valve to open $\frac{1}{80}$ in. when the pressure in the boiler is 22 lb. per square inch above the weight per square inch on the valve. Collecting the results of these experiments, we have the following Table:—

TABLE I.

Diagrams.	Total pressure in boiler in lbs. per square inch, including the atmosphere.	Weight on the valve in lbs. per square inch where the valve lifted the under-mentioned fractions of its diameter; diameter = 1 inch.				
		$\frac{1}{80}$	$\frac{4}{80}$	$\frac{8}{80}$	$\frac{12}{80}$	$\frac{16}{80}$
A	65	58½	53⅔	52¼	51½	...
B	65	57¾	53¼	51⅓	...	...
C	73	58½	54	52¾	...	...
D	65	53½	49½	48¾	48	...
E	67	59	48¾	...	...	...
F	70	61½	50	48¾	...	...
G	65	56½	45½	...	...	...
H	65	55½	51	49	47½	46½
I	65	54¾	52½	50¾	49½	...
J	65	57½	48	44½	...	...
K	65	58½	54⅓	...	...	...
L	67	56¼	52	49½	48½	47½
M	67	45	...	...	...	...

Many valves, from 2 in. to 5 in. diameter, may be seen on boilers blowing very faintly when the pressure in the boiler is from 15 lb. to 20 lb. per square inch above the weight per square inch on the valve. This is the case more especially when the valve is a disc, and the facing similar to that of experiment M. We see from experiment M, as an extreme case, that if the pressure in a boiler be 45 lb. on the square inch, the pressure would rise with a valve of that construction to 67 lb. before the valve could lift $\frac{1}{80}$ of an inch, or cause the valve to open $\frac{1}{20}$th of its area of aperture. These experiments prove that we cannot have the *common safety-valve* of sufficient area to allow the steam, when the furnace is in full action, as rapid an exit as it ought to have, unless the valves be very large. It is important that we know what size of an aperture will be just sufficient to take away all the steam that can be generated in a boiler so that the pressure shall not rise above a given amount; and since this depends on the quantity of fuel consumed and the quantity of water evaporated in a given time,

Let $f =$ the area of the firegrate in square feet.
$c =$ pounds of coal consumed on each square foot of firegrate per hour.
$e =$ pounds of water evaporated per pound of coal consumed.
$q =$ quantity of water evaporated per second in pounds.

Then
$$q = \frac{cfe}{3600} \text{ lb. per second.}$$

It may be shown that
$$v = 96\sqrt{\frac{p}{w} \cdot \log_{\epsilon} \frac{p}{x}} \qquad \ldots \quad (2)$$

or
$$v = 7392{\cdot}5\sqrt{p^{\cdot 059} - x^{\cdot 059}} \qquad \ldots \quad (3)$$

In equation (2) w equals the weight of one cubic foot of steam at pressure p, and in (2) and (3) x equals the pressure of the atmosphere, or any pressure of steam less than p.

The value of v in (2) and (3) is the maximum velocity of flow when the expansive action of the steam is taken into account, and represents the rate of flow when the density of steam passing through the aperture is considered as equivalent to steam at pressure x.

But if we require the velocity of flow of steam of the same density as that in the boiler, we have:
$$v : v_1 :: s_1 : s;$$
$$\therefore v_1 = \frac{vs}{s_1} \qquad \ldots \qquad \ldots \quad (4)$$

where v_1 is the velocity of the steam issuing at the density of that in the boiler, and s_1 the volume in cubic feet of one pound of steam at pressure x, and s the volume of one pound at pressure p.

Hence
$$v_1 = \frac{s}{s_1} \cdot 96\sqrt{\frac{p}{w} \cdot \log_{\epsilon} \frac{p}{x}} \qquad \ldots \quad (5)$$

or
$$v_1 = \frac{s}{s_1} \cdot 7392{\cdot}5\sqrt{p^{\cdot 059} - x^{\cdot 059}} \qquad \ldots \quad (6)$$

Now qs = the volume of steam to be delivered of the same density as that in the boiler, through the aperture a; therefore,

$$a = \frac{144\,qs}{v_1} \quad \dots \quad \dots \quad (7)$$

Substituting the value of q from (1), and making k the coefficient of contraction, we have:

$$a = \frac{cfes}{25v_1k} \quad \dots \quad \dots \quad (8)$$

which will give the area in square inches of aperture through which the steam issues into the atmosphere, so that no danger may arise from over pressure.

This area is not the area of the safety valve, but the area of that portion of it which is open to the atmosphere for the issue of steam.

Before we can find the value of a, we require the other values of the right-hand member of the equation (5) which are to be taken as follows:—

Make f = one square foot.
$c = 20$ for stationary and marine boiler.
$c = 100$ for locomotive boilers.
$e = 6$ lb. of water evaporated per pound of coal.
$k = \cdot 8$.

These may be taken as constants in (5), which for stationary and marine boilers becomes

$$a = \frac{6\,s}{v_1} \quad \dots \quad \dots \quad (A)$$

$$\text{or } a = \frac{6\,s_1}{v} \quad \dots \quad \dots \quad (9)$$

Now s may be taken from the experiment of Messrs. Fairbairn and Yate, or calculated by the following formula:—

$$s = 330 \cdot 36 p^{- \cdot 941} \quad \dots \quad \dots \quad (10)$$

which gives nearly the same results.

We have no experiments for the values of v_1 or v, but we know that when the formula here given for v_1 applied to the apertures for admission of steam to the cylinders of steam-engines, the velocity of steam calculated by the formula (5) or (6) agrees with practical results, or, in other language,

$$v_1 a = \mathrm{V\,A} \quad \dots \quad \dots \quad (11)$$

where v_1 is the velocity of the steam, a the area of the aperture allowed by the valve for admission to the cylinder, and V the velocity of the piston, A being its area.

This being the case, we may presume fairly that the data are experimentally sufficient, and that no purely theoretical areas are herein intended.

The following Table will give us the values of s and v, when p is known, by using which, in equation (6), we get the values of

TABLE II.

Date.				Area of safety-valve opening in square inches per square foot of fire-grate.	
Absolute pressure of the steam in pounds per square inch.	Volume of one pound of steam in cubic feet.	Velocity into the atmosphere in feet per second of density, s_1.	Velocity into the atmosphere in feet per second of density, s.	Stationary and Marine.	Locomotives.
p.	s.	v.	v_1.	a.	a_1.
14·7	26·5000				
20	19·7133	1017	757	·1563	
25	15·9801	1374	829	·1157	
30	13·4602	1606	816	·0990	
35	11·6413	1782		·0892	
40	10·2665	1928	747	·0824	
45	9·1905	2046		·0777	
50	8·3222	2148	676	·0740	·3500
60	7·0099	2318	613	·0685	·3425
70	6·0640	2455		·0643	·3215
80	5·3479	2569	518	·6619	·3095
90	4·7874	2667		·0596	·2980
100	4·3351	2753	451	·0576	·2880
120	3·6515	2898		·0549	·2725
130	3·3870	2961		·0536	·2680
150	2·9600	3070	343	·0518	·2590
200	2·2582	3283		·0472	·2360
300	1·5419	3573	278	·0450	·2250

a given in the Table, also of a_1 for locomotives, which is simply

$$a_1 = 5\,a \quad \dots \quad \dots \quad (12)$$

The values of v_1 will be found to decrease with the pressure after passing its maximum, corresponding to

$$\frac{x}{p} = \cdot 54496,$$

$$\text{or, } p = \frac{x}{\cdot 54496} \quad \ldots \quad \ldots \quad (13)$$

And when $x = 14 \cdot 7$ the maximum flow of steam is delivered when the pressure in the boiler is 37 lb. absolute.

If we have a boiler of the stationary or marine class containing 32 square feet of firegrate, and the pressure, *p*, in the boiler is not to exceed 80 lb. absolute, or 65 lb. above the atmosphere, we have in column *a*, opposite 80 lb., the value ·0619, which being multiplied by the area of the firegrate, gives

$$32 \times \cdot 0619 = 1 \cdot 9808$$

square inches as the area of the aperture in the safety valve for the passage of steam from the boilers into the atmosphere.

Any one who has observed the common lever safety-valve knows that when the steam is blowing off under the action of a hot fire, and no other exit open in the boiler for the escape of steam, that the valve rises very little from its seat; in fact, if the valve be 5 in. diameter, it must rise ·103 in. from its seat to make the area of exit equal to 1·98 in., as given by the table for a 32 square feet grate, the pressure being 80 lb. absolute.

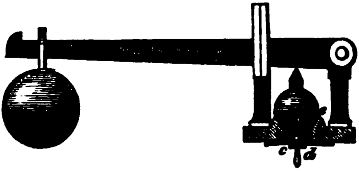
It is very probable that if this valve was weighted to 80 lb. on the square inch, the pressure would rise at least to 90 lb. before the valve lifted ·103 in.; and if the valve be of the disc kind, the pressure might rise to 100 lb. before the valve lifted ·103 in.

To prevent the increase of pressure in steam boilers, it is necessary to have a safety-valve that will open sufficiently to prevent much increase of pressure over and above that at which the valve is weighted to blow off, and, at the same time, not open too large an area for the escape of steam.

It has been shown that an opening of 1·98 square inch will prevent the detrimental increase of pressure in a boiler having an area of firegrate of 32 ft., and an absolute pressure within the boiler of 80 lb. per square inch.

A valve of the construction shown in the following figure, having a diameter of 1⅝ in., and weighted to 80 lb. on the square inch, will, before that pressure can be exceeded 1 lb. lift sufficiently

Fig. 19.



to open an aperture equal, or nearly so, to 1·98 square inches; whilst a valve of the common kind would allow the steam to increase at least 10 lb. above the working pressure before it would lift sufficiently to open an equal aperture.

The valve *a* is a solid of revolution, or a portion of it, a sphere being sufficient so that it may have the chance of moving occasionally on its seat; *b* is the opening from the boiler, *c* being a guard through which the small spindle *d* passes.

The valve *a* is weighted in the ordinary manner, either by a lever and weight or direct. The valve-seating projects as shown at *e*, and very nearly touches the valve *a*.

When the valve lifts by the steam in the boiler being only slightly in excess of the weight on the valve, very little steam passes; but if the steam continue to increase in pressure, the valve *a* is forced open, so that a passage equal or nearly so to the area of the valve is open, and the steam is thereby prevented from increasing in pressure by being discharged from the boiler, from which we see that this small valve is at least twenty times as efficient as one of the disc kind five times its diameter.

It is well known that during the night, as well as at other times, the steam in boilers will rise and blow off from the safety-valves, and often at a considerable pressure above that at which the valve is weighted, which in the case of old or strained boilers is very dangerous, and often has been the cause of the most disastrous explosions; for the fireman looks often to the safety-valve alone, without noticing the steam-gauge, and sometimes gauges get wrong as much as 20 lb., in which cases, when they happen together, the greatest danger is to be apprehended where the common safety-valve is used; but if one or two of these small va had been placed on the boiler the excessive pressure would have been prevented.

The construction of these valves is such that they are not liable to stick, and being small, and requiring comparatively about twenty times less weight, are better to handle and cheaper, as well as more efficient, than the large unwieldy valves used for high pressures, never requiring to be greater than about 1⅝ in. diameter for high-pressure boilers, and often not more than 1 in. diameter.

For agricultural steam-engine boilers this valve need not exceed 1 in. diameter, and would liberate as much steam as the boiler could produce at 50 lb. pressure.

For locomotive boilers the diameter of the valve need not exceed 1½ in., and for the excessively large stationary boilers 2 in. diameter will suffice, and in many cases 1 in. diameter will be ample.

For marine boilers, where the pressure is low, this class of valve need not exceed 2 in. diameter, but in many cases 1⅝ in. diameter will be sufficient.

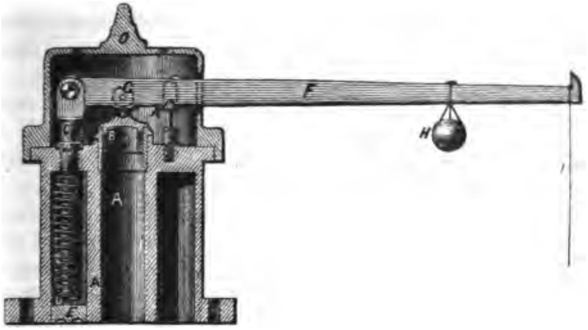
This valve is also applied to act as a low-water valve by the application of a lever and float inside the boiler, and for that purpose need not exceed 1¼ in. diameter, but in the majority of cases 1 in. will be sufficient. Several of these valves are at work, and have been experimented upon and found to be very efficient.

If any one will take a piece of writing-paper about 1 in. diameter, and place it on the open part of the head of a common tobacco-pipe, and insert in the paper three small pins as guides, he will find it utterly impossible to blow the paper disc off the pipe by blowing down the stem. This simple experiment gives us a good insight into the nature of safety-valves of the disc class."

(*b*) The following description and illustration of *Swann's Safety Valve*—which was shown at the Paris Exhibition—are taken from the "Practical Mechanic's Journal" for Jan. 7, 1867.—"The ingeniously contrived safety valve of which the annexed woodcut represents a vertical section, has been recently patented by the inventor, Mr. J. R. Swann, of Leith Walk, Edinburgh, and has for its object the prevention of undue weighting of the valve, and the consequent explosions resulting from such a practice.

It is also so arranged as to come into action when the water in the boiler gets dangerously low. The construction and operation of this safety valve will be readily understood on referring to the illustration, and the following brief description. A, fig. 20, is the valve casing, B the top of the valve, C the rod or pin for fixing the end of the lever, F such rod passing down to the bottom of the valve case; D is a helical spring secured by a nut on the lower end of the rod C. The escape of steam through the chamber containing the spring and rod C, is prevented by inserting a plug at E. G is a movable pin or lever F, for coupling it with the valve, B. H is the weight, I a float wire attached to the end of the lever, and descending to a float inside the boiler, and K is a fulcrum for the valve lever fixed inside the case, and slotted to retain the lever in its place. O is the cap or cover of the valve. Supposing the lever to be weighted to its proper maximum pressure, it is obvious that if additional weight be applied the lever will be brought in contact with the fulcrum K, and the opposite or inner end of the lever will be consequently elevated, and caused to act upon and compress the spring D, the valve being thereby lifted and allowing the steam to escape. Thus any tampering with the valve is rendered futile. Should the water in the boiler get too low, the weight of the float, by acting upon the end of the safety-valve lever, will produce the same result as

Fig. 20.



the overweighting of the lever, and allow the steam to blow off, thereby calling the attention of the fireman to the position of the water level."

(*c*) On the subject of "safety-valves" the "Engineer," under date of March 1st, 1867, had a paper, from which we take the following:—"At a remote period in the history of the steam-engine, thin copper plates were fitted to apertures in the tops of the boilers by way of safety-valves. If the pressure became too great, the copper gave way; it was blown out *en bloc*, and the steam escaped. If, now, we place a safety-valve on a boiler, and load it, say, by a weight suspended inside the shell, we shall have something analogous in one sense to the copper plate; and any person who had never seen the apparatus at work would say that the valve being held down by a certain load would be raised and ejected bodily, like a soda-water bottle cork, the moment the pressure at all exceeded that to which it was loaded; indeed, this ejection would actually take place if water acted on the valve instead of steam. Now, in practice, we know that nothing of the kind takes place. As soon as the pressure just exceeds the load, the valve will rise very slightly from its seat; as the pressure increases, it will rise higher and higher; but it will not be ejected forcibly under any circumstances which ordinarily arise. Let us now examine these phenomena a little more closely. We find that by the first rise of the valve steam is permitted to escape, and a current is established. A longer or shorter pillar of steam ascends continually beneath the valve, at a greater or less velocity according to the area of the opening left by the rise of the disc, and on the top of this column the valve floats, as it were suspended like Mahomet's coffin. It is evident from this that the distance to which the valve rises from its seat bears a definite relation to the pressure exerted beneath it. Thus, if we suppose that it cannot with a given load be kept from rising with a given boiler pressure to a distance equal to the one-hundredth of an inch from its seat, by increasing the boiler pressure a few pounds the distance may be increased to perhaps one-tenth of an inch, and so on. It is clear, therefore, that when the valve rises slightly, the pressure of the steam on its under side is diminished. This appears to be indisputable. The force tending to lift the valve and the force tending to keep it down must balance each other, or else the valve, moving in obedience to the more powerful of the two, will open still further, or close. The pressure immediately under the valve is in all cases measured by the load on it; but the pressure immediately under the valve and that in the boiler are not identical, and, therefore, the load on the valve does not measure boiler pressure. The load on the valve measures the pressure under the valve; but we cannot measure the boiler pressure even indirectly by its aid, unless we can previously determine the proportion which the pressure beneath the valve bears to that in the boiler. The difference between the two is usually very clearly marked, and the problem presented for solution is simply to determine why the pressure on the face and conical sides of the valve is less than that in the boiler. In the first place, as steam possesses weight and momentum, the ascent of a column tending to the orifice of escape ought to increase the pressure on the valve as a result of *vis viva;* but, apparently, no such action takes place. If we fix the safety-valve on the top of a long tube, the difference will be more marked than if the valve is fixed on the boiler shell directly; and we can in this case imagine that something is lost by the frictional resistance due to the sides of the pipe. But all this in no way affects the fact that a safety-valve fitted immediately on the shell will sit balancing on a pressure of steam much greater than that to which it is loaded without rising or falling, unless an additional force is impressed on it. As a rise of much less than the hundredth part of an inch will suffice to render this manifest, it follows that the reduction in pressure must take place within this space; or if we may be allowed to use the illustration, we may suppose that just under the valve there is a film of steam, say, the one-hundredth part of an inch thick, one side of which exerts a pressure equal to that in the boiler, while the other exerts a pressure equal to that to which the safety-valve is loaded. This statement may appear absurd, yet it is impossible to resist the conclusion that it very nearly expresses exactly what takes place beneath a safety-valve whenever steam blows off.

There is only one theory which will explain this phenomenon, and in the absence of extended and careful experiments which have yet to be carried out, it is impossible that the theory can be otherwise than crude. It seems probable that the current of steam splits up at a point close beneath the valve, and that by some peculiar action analogous to that of an induced current, a partial vacuum is produced at or about this point. Precisely what part the external pressure of the atmosphere plays it is impossible to say. The question can only be set at rest by causing a valve to blow into a vacuum, maintained by the condensation of the steam as it enters. If it could be seen that, under ordinary circumstances, a partial vacuum was found beneath the valve, all the phenomena might be explained on the theory of two springs acting in opposition. When a valve is held down by a spring balance, it is, of course, clear that with each rise in the lever the load on it is increased. As the peculiar phenomena under consideration are, however, manifested just as clearly when the valve is held down by a weight, we have preferred to simplify matters by avoiding all allusion to a spring balance up to this point; but it must be remembered that every safety-valve is loaded by both a spring and a weight. The safety-valves of a locomotive are held down, first by their own weight and that of the lever and its appurtenances, and secondly by the atmosphere, which constitutes one spring, and then by the wire, which constitutes another. The safety-valve of a land boiler is held down by its own weight and that of its lever and ball, and by the spring of the atmosphere. In the first case the load is increased by raising the valve, and thereby compressing or extending the spring. In the second case the load is not increased by raising the valve, as the air is not compressed. If, however, a partial vacuum is formed beneath the valve, the load will be virtually increased, the pressure of the atmosphere remaining constant. Whether the induced current does or does not produce this effect with all forms of valve remains to be seen; but it is certain that large disc valves are actually pinned down close to their seats by the action of a current escaping between the two surfaces."

16. *Steam Gauges.* (*a.*)—"Nothing," says the "Scientific Review," under date October 1st, 1867, "Nothing can be more conducive to the prevention of steam-boiler explosions than a reliable means of ascertaining the level of the water within the boiler, and an automatic indication that it has become too low, from any cause. Many contrivances, more or less effective and ingenious, have been devised for the purpose. A very simple

one, the invention of an American, is coming into use in the United States. It consists in surrounding a short tube, which issues in a horizontal direction from the boiler, just beneath the proper water-level, with a jacket containing water. So long as the tube is filled, as it should be, with water, and not with steam or foam, water remains between the jacket and tube; but when there is no water in the pipe, the water in the jacket evaporates, forming steam, which blows a steam-whistle, and even, if desirable, opens a safety-valve that permits steam to escape from the boiler."

(*b*) *To keep Mercurial Steam Gauges perfectly clean inside.*—"General experience has shown that the mercurial steam gauges in the course of time often become dirty in their interior by mercury and its oxide adhering to the glass, so that it is very difficult to see the position of the surface of the mercury. The consequence is, of course, an uncertainty as to the amount of steam pressure. A simple and very effective remedy is, to bring on the surface of the mercury a little glycerin; this serves as a lubricator for glass and mercury, covering the surface of both, preventing their immediate contact, and consequently all adhesion, and keeping it always clean and bright. This simple remedy is spoken very highly of by all who have tried it."—*Scientific American, Dec.* 1, 1866.

(*c*) The same Journal has the following remarks upon *Boiler Feed Pipes, Check Valves, and Cast-iron Heads.*—"From a correspondent, G. W. D., of Providence, R. I., we have received some account of a boiler explosion which lately took place in Massachusetts. One of the boilers in a nest of eight, burst, displacing the remaining seven aud carrying destruction in the path of its fragments. The boiler was rent in two parts, one part imbedding itself in the chimney and the other flying two hundred feet, cutting through a telegraph pole, damaging a railroad embankment, tearing up the rails and plowing a furrow in the ground, after striking, two feet deep and two hundred feet long. The superintendent of the works attributed the explosion to excess of water in the boiler, but our correspondent thinks it was occasioned rather by absence of water.

The nest of boilers was fed with water by a common pipe, having branches leading to each boiler, and one check valve on the main pipe between the pump and nearest boiler. Our correspondent believes that unequal firing disturbed the equilibrium of the water; in other words, that firing under one boiler more than under another will create a greater pressure of steam in that boiler, forcing the water out into the cooler boilers, thus leaving the boiler which bears the most intense heat without an adequate supply of water.

He approves of introducing a check valve to every boiler to prevent the water from being driven out of one boiler into another, and, better than that, to employ competent men to manage boilers in sets.

It seems as though there could be only one place to which the check valves could be applied, and that would be in the branch pipes leading from the main feed pipe to each boiler. If placed in the main horizontal pipe they would prevent the water from backing into one boiler, but not into that on the other side. If the water-feed pipes are large enough and the connection between the steam spaces ample, it seems there should be little trouble in equalizing the pressure and the level of water in the different boilers without any check valves. Preferably, independent feed pipes to each boiler should be employed; then each boiler could be treated as a separate generator. If not, would it not be well to introduce cocks between the boilers to be attended by the fireman or engineer? Sometimes one or two boilers of a nest are used while the others remain idle. In this case there is a means to stop both water and steam communication between those in use and those at rest. Under such circumstances the equilibrium must depend upon the knowledge, carefulness, and attention of the fireman, or the constant oversight of the engineer.

A similar explosion to that mentioned by G. W. D. is described by a correspondent from Jacksonville, Fla. In this case the boiler that exploded was the middle one of three plain, cylindrical boilers, forty feet long and forty inches diameter. The cast-iron head blew out, the disc cut from the flange as evenly as though turned off in a lathe. The head itself merely blew out and lodged at the foot of the chimney directly behind the boiler, while the shell went at least three hundred feet, cutting timbers off clean and dragging its two companions from their beds about their own length. The writer attributes the blowing out of the cast-iron head to its vibration by alternate expansion and contraction, or bulging by being heated during the day and cooled during the night. This is undoubtedly the reason why it gave way as it did, but why should that particular boiler head yield and not either of the others? More internal pressure was exerted on this boiler than on the others, or all would have gone and at the same time. Our informant does not describe the means of communication or of separation between the boilers, but only says, "there was abundant means of communication both for water and steam between all these boilers, and no greater pressure could exist in one boiler than in the others." The explosion took place in the morning before the machinery had been put in operation. The watchman states that there was plenty of water and the steam gauge stood at seventy pounds. The engineer says he left the boilers the night before with three gauges of water, and our correspondent deemed the sound of the whistle which he heard a few minutes before the explosion not to indicate a high pressure of steam. All this may be, and yet there may be circumstances in regard to the communication between the boilers which are not mentioned by our correspondent which would, in a measure at least, afford a probable reason for the explosion. We knew a case where a boiler in a set was exploded when ample means of communication existed, but the steam and water connections could be closed by cocks. Notwithstanding the asseverations of the fireman, it was evident that the exploded boiler was without a proper supply of water. If the steam communication was closed and the water communication open between the different boilers, and one boiler was fired harder than another, it would not require a very great preponderance of steam pressure to empty the water from the heated boiler into the others, leaving that one in a most dangerous condition.

As to making cast-iron heads thick enough to prevent springing, it may be questionable whether this would be as effectual and economical a remedy as making them of wrought iron and of hemispherical form, as is the practice in England. This is a far better form to resist internal pressure than the flat disc head. In flue-boilers the flues themselves are usually the only stays employed in retaining the heads in position, but the expansion of the flues is sufficient to exert an enormous force on the heads.

It is no wonder that explosions occur from this cause; the wonder is that they are not more frequent."—*June* 8, 1867.

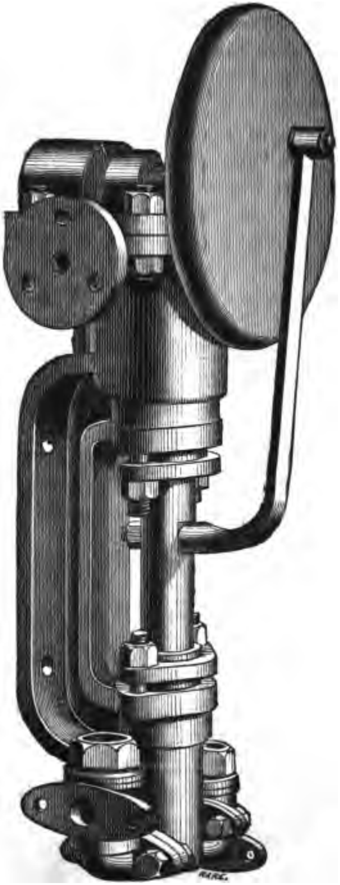
17. *Some Boiler Appliances as shown at the Paris Exhibition of* 1867. In Plate VI., fig. 1, we give drawings of the Boiler Feed Apparatus, which was exhibited in the American Department, and which is patented by Mr. G. A. Riedal of Philadelphia. It has for its object the doing away with feed-pumps, and is thus described in "Engineering," under date May 24th, 1867 :—" A is a copper receiver for the purpose of holding a certain supply of water always in readiness for feeding the boiler, and through the centre of this receiver passes a tube, S, from its bottom nearly up to the top; at the top the receiver is fitted with a small cock, I, which is opened to allow the air to escape when water is at first admitted into it. This receiver is held by a bracket at one end of a lever, E, at the other end of which is a counterbalance weight, C, and a small guide-bar, with piston working in the cylinder at P, supports the receiver when full, and steadies its upward motion when it falls short of water, and is consequently raised to the position shown by the dotted lines. At the bottom the receiver is connected by two pipes, B^1 and S^1, with the inside of the boiler, the pipe B^1 passing down to near the bottom of the boiler, whilst the pipe S^1 reaches only to the level of the proper water-line. A third pipe, W, leading from the valve, W^1, communicates also with the pipe, S, inside the receiver at one end, and with a reservoir of water at the other. Before the apparatus is prepared for work, and when the receiver is empty, it takes the position shown in the dotted line; but, in order to charge it, the tap, I, is opened, and water is permitted to run in from the reservoir or tank through the tubes, W and S; to ensure which it is only necessary that the water-level in the tank should be about in a line with the top of the receiver when empty. The tap, I, is then closed, and the receiver, being full, raises the weight, C, and assumes the position shown in the full lines, and at the same time the valve, W^1, is closed by the action of the small lever above it, and the valves, L and L^1, are opened, the one opening a communication between the pipe, S^1, in the boiler and the pipe, S, in the receiver, and the other between the pipes, B and B^1, the latter of which enters the receiver and communicates direct with the lower part of its interior, as the pipe

S^1 does with its upper part. As soon as the water-level sinks below the orifice of the pipe, S^1, steam rushes up into the top of the reservoir, and so causes an equal pressure on the top of the water in the receiver and on the top of the water in the boiler, so that the water in the receiver flows down into the bottom of the boiler by its own gravitation; when the water in the boiler is above the orifice of the pipe, S^1, water is prevented from being driven from the boiler into bottom of the receiver through the pipe, B^1, by the stop-valve at R. As the receiver, A, becomes emptied, steam takes the place of the water, which, being so much lighter than water, will cause the counterbalance weight, C, to bring the receiver into the position indicated by the dotted lines, closing at the same time the two valves, L and L^1, and opening the valve, W^1, in the supply-pipe, W. The steam in the receiver, being thus brought into contact with the feed-water, rapidly condenses, and, forming a vacuum, causes the receiver to fill, when it is again at once brought into its former position. The main feature in the apparatus, distinguishing it from others of a similar kind previously proposed, is, that as the receiver rises and falls, the lever, E, traverses over its fulcrum, D, and its two arms thus vary in length. This alteration in the effective lengths of the arms of the supporting lever enables the receiver to remain steadily in its upper or lower position until its weight is materially increased or reduced, as the case may be. By this means the water in the boiler is constantly kept at a certain level, thus preventing the possibility of an explosion by low water, as well as the inconvenience of carrying the water too high in the boiler; and, by attaching a counter to the machine, the exact amount of water that has been used from time to time may be registered."

In fig. 6, Plate VI., we illustrate the form of apparatus invented by M. Lemaillier-Pinel for indicating the level of the water in the boiler, and for giving notice also of either a deficiency or an excess of it. Very favourable opinions have been elicited from authorities respecting this apparatus, of which 8,000 have been already sent out by the maker, and the "Engineer," under date August 30th, 1867, endorses these favourable opinions. Our drawings are reduced from those which this journal gives, and the following is an epitome of the remarks which accompany them. In view of the difficulties attendant upon the working of the ordinary form of gauge-cocks, and all "glass gauges," which do not give indications at all times trustworthy, many engineers prefer to fall back upon the internal float, with its outside index, as that form of apparatus which gives the most trustworthy indications; but in this apparatus the difficulty has been, as put by the writer in the "Engineer," "to find a method of connection between the inside and the outside of the boiler without friction, and when once adjusted, without the probability of derangement." It is to the solution of this problem that M. Lemaillier-Pinel has directed his attention, and, as the above authority says, with "remarkable success." The agency with which the inventor operates is "magnetism." The float used is relatively large, is of copper, and is so weighted that the line of the junction of the two segments of which it is composed is coincident, when it floats, with the level, or true level, of the water in the boiler. The vertical pipe on the outside of the boiler is made in three parts, the lower one cast iron, the middle one of gun-metal,—of which metal also is the screw collar connecting the tube with the boiler. The upper part of all is of brass, and is furnished with a flat side, this side having marked upon it a line corresponding to or indicating the normal water level in the boiler, and above and below this line gradations of centimetre distances. The tube thus arranged is crowned with the "manometer steam-gauge," as shown in fig. 2, Plate VI. This vertical pipe is furnished at one side with a steam whistle; if two are provided, the one at the lowest point in the tube indicates, when it works, a deficiency, the one at the highest point, an excess of water. The wire or rod of the copper float passes freely through the lower gun-metal collar, and also through a collar placed at the bottom and at the centre of the middle piece of the vertical tube, which, as before stated, is made of gun-metal. "The top part of this rod is provided with a flat piece, to which is screwed or riveted between cheeks of brass a powerful permanent bar magnet. The upper or south pole of this magnet is bent at right angles to the rest of the piece, and rounded and polished at its extremity, which, when the carrying rod is vertical and in position, rubs with very slight friction against the smooth back face of the graduated brass plate. At the rear of the magnet-carrier is fixed a slight spring of hard gun-metal, which bears with gentle pressure against the interior of the pipe opposite it, and thus insures the upper pole of the magnet remaining always in contact with the back of the graduated plate. The float, by its form, secures the constant perpendicularity of the float-rod. The two collars through which it freely passes within the pipe, prevent departure from this beyond narrow limits. Within these limits alone the small spring is needed. Before the glass plate outside the graduated brass one is closed, a black varnished or blued steel index, in the form shown at full size in fig. 3, is placed horizontally and loosely at the bottom. It is instantly caught up by the upper pole of the magnet inside, as soon as this is depressed so as to come near it, and it thereafter remains always in suspension, in close contact with the graduated brass plate, and at whatever level upon this corresponds with that of the top pole of the magnet inside. The horizontality of this magnetic index or armature is secured by the form of the top pole of the magnet itself, which, being a flat bar bent as has been described, has its pole, when in contact with the back of the scale plate, also horizontal, *i.e.*, the contact is a horizontal line. It remains only to describe the arrangement by which the whistles are set agoing. As regards the lower one, which is shown on fig. 3, plate VI., this needs but a few words. The adjustable collar and tappet seen upon the float rod when it comes in contact with the little latch lever of the whistle-valve, pulls the latter inward with a force equal to the momentary unsupported weight of the float; and as the absolute weight of this is considerable, and the area and friction of the steam-valve are very small, there is ample force to effect this. When the float rod has descended to this point its uppermost collar rests upon that of the pipe, as will easily be seen in fig. 3, plate VI., so that the little touching piece or cam on the rod cannot descend below the latch lever of the whistle-valve, and on the float again rising this latter is released, and the whistle-valve closes of itself. But the apparatus may also be so arranged that once the float has been depressed to this position through the carelessness of the stoker, the instrument will not rise to zero again until readjusted by hand, so that it then becomes a tell-tale, even though the whistle's voice be stifled. The arrangement for blowing a whistle for showing too much water is almost precisely similar, but placed and acting in a reverse direction."

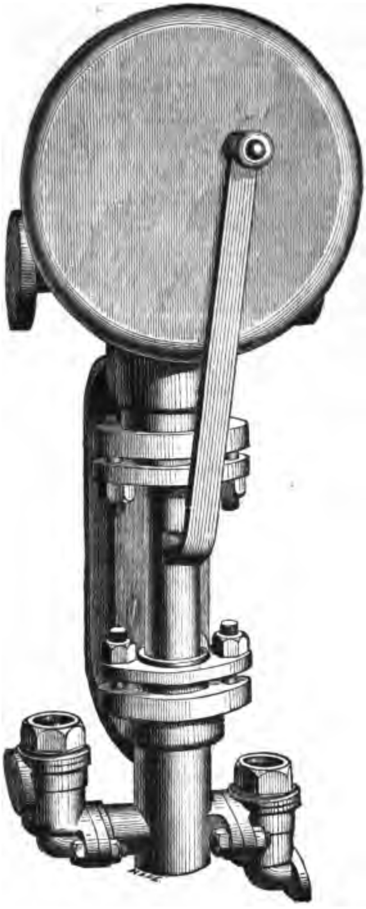
In a former vol. of this work we described the apparatus for supplying boilers with water, known as "Giffard's Injector," as possessing certain advantages over the ordinary form of feed-pump, the disadvantages of which were also stated. The injector, how-

Fig. 21.



ever, is itself possessed of some disadvantages, which it is our duty here to note. In the first place, it is a somewhat delicate instrument to work; it is possessed, so to speak, of a peculiar idio-

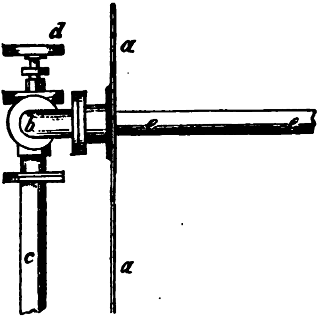
Fig. 22.



syncracy, which renders it sometimes very capricious in its working. It will not work where water is employed above the temperature of 120°, the best temperature being 32°, and, further, it will not draw water from a greater vertical depth than 6 feet. The feed-pump and the injector, then, being possessed of disadvantages, the "donkey engine," as it is called, is rising in favour. This, as some of our readers may not be aware, is a small separate steam-engine, the duty of which is merely to pump the water into the boiler. Very successful have these engines been, as they are capable of drawing water from the full practicable depth influenced by the vacuum, and when out of order are easily repaired. Still they have at the best been so comparatively complicated in their parts, that their consequent cost has kept many from using them. The drawings in figs. 21 and 22, represent a form of donkey engine, which, for simplicity of construction, and from the ease with which it is set at and maintained at work, and also from the ease with which it is repaired, is, we have no hesitation in saying, one of the best forms of apparatus for supplying boilers with water yet introduced. It is capable of pumping boiling water, and from the full practicable depth or distance; it can be set to work also with a pressure of steam in the boiler as low as 15 lb. to the square inch, and by merely giving a larger cylinder, or using the next size to that required to do certain work, as low a pressure as 10 lb. steam can be used. They work freely at a rate of 150 revolutions per minute, although we have seen them work at a higher rate than this, delivering the water to the boiler with the greatest precision; while, by adding an air vessel to the delivery pipe, they can be worked at a speed double the above amount. Even at this speed, such is the admirable simplicity and careful construction of the whole arrangement, that the work is done with the utmost smoothness, and the absence of all jar and knocks—a most telling circumstance in its favour, for whenever there is jar and noise in the working of machinery the user may rest assured there is loss and bad working. We understand the manufacturers are about to introduce an arrangement for farm purposes, by which, in small compass, a boiler and engine complete can be set to work for pumping water from a high to a low level, and made applicable to many of the purposes of the farm. The sketches—fig. 21 being a side and fig. 22 a front elevation—we give are so clear that the reader will be able at once to note the arrangement of this ingenious adaptation of steam power to such important purposes as it is designed to serve. This form of donkey pump is patented by Messrs. Brown, Wilson and Co., of Vauxhall Iron Works, London.

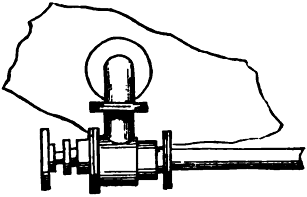
18. *Points of the Boiler at which to supply Water.*—In supplying a boiler with water, it would seem a very unimportant matter at what point the water was injected. Usually, almost always, the water is supplied to the lower part of the boiler. By this plan it is found that there is a tendency to strain the bottom lines of rivets, by contracting unduly the plates, this being more especially the case when the water is cold; but it is observable even when it is heated to as high a temperature as 200°. Another disadvantage of this method of introducing the feed-water at the bottom is, that in cases where the boiler-furnace is "banked up"—that is maintained at a low rate of combustion—the water is apt to become drained off, if the valve of the feed is defective, laying bare the crown of the flue. Both these evils are obviated by the simple plan now recommended by the Manchester Association for the Prevention of Steam-Boiler Explosions —"of introducing the feed-water near to the surface of the water in the boiler, and passing it through a series of perforations made at the further extremity, as shown in fig. 23, where *a a* is

Fig. 23.



the front plate of boiler, *b b* the feed-box, supplied by the pipe *c*, and worked by the wheel *d* on the pipe. The feed-box is usually placed in boilers at the top, completely beyond the reach of the fireman. In this arrangement it is placed, as shown at fig. 24, at the front of the boiler, so as to be within his easy reach." For constructive details of this very excellent arrangement—by which the water is delivered to the interior of the boiler in a shower or spray, and by which it attains the same temperature as that at the bottom plates—the reader is directed to the number of the *Practical Mechanics' Journal* for November 1866.

Fig. 24.



19. *Priming Preventer.*—A simple and ingenious contrivance has recently been invented by M. Lugnes for preventing priming or the discharge of water with the steam in the steam pipes of boilers. The apparatus consists of a short cylinder placed at the top of the horizontal part of a steam generator with its axis disposed at right angles to that of the axis of the boiler. The steam pipe proceeding from the dome opens tangentially into the cylinder through one side. The outlet pipe is forked, each branch opening into the cylinder in the centre of the two ends thereof. A fourth opening made in the bottom of the surface of the cylinder communicates with a pipe which descends to the bottom of the boiler. When the cocks of the steam pipe are opened, the steam entering the cylinder under pressure in a tangential direction acquires a rapid rotatory or whirling motion, and escapes by the two central openings at the ends. During

this gyratory motion the drops of water conveyed along with the steam into the cylinder are, by centrifugal force, carried towards the sides, and accumulate there. The water will, therefore, escape through the vertical pipe which proceeds from the bottom of the cylinder, and return to the boiler; whilst the dry steam passes through the pipes fixed to the centre of the cylinder ends, whence it is conveyed to the engine.—*Practical Mechanic's Journal*, July 1867.

SECTION THIRD—BOILER EXPLOSIONS, &c., &c.

20. Amongst the Reports and Papers looked for with interest which bear upon this subject, are the Reports of the "Manchester Association for the Prevention of Steam Boiler Explosions," of which Mr. Fletcher is the engineer-in-chief, and of the "Midland Boiler Association," of which Mr. E. B. Marten is the engineer. Under (*a*) we give from one of the monthly reports of the first named of the above Associations, a few extracts bearing upon some points of importance; and under (*b*) extracts from the Annual Report of the Midland Boiler Association, for the illustrations of which we are indebted to the courtesy of the engineer of the Association.

(*a*) *Injury to Furnace Crowns.*—"The case referred to arose through the attendant's leaving the blow-out tap of his boiler open with the fires burning. The boiler, which was one of a series of three set side by side, and connected together, had recently been let-off for cleaning, and the fireman was getting up steam to set it to work again, when, observing that there was more water in the gauge glass than was necessary, opened the blow-out tap at the bottom of the boiler to lower it, and, forgetting a few minutes after that he had done so, went away to oil the machinery, leaving the boiler with the fires burning and the water running out through the open tap. He was absent about a quarter of an hour, and on his return found the boiler empty, and the furnace crowns red hot. The boiler was fitted with a low-water safety-valve, as well as a fusible plug on each furnace, but as there was no steam the safety-valve could sound no alarm, and as there was no water, though the fusible plugs both melted, the fires were not damped. In such cases as this, which are by no means infrequent, of fires being left burning in empty boilers, it is clear that neither low-water safety-valves nor fusible plugs are of any avail, though the difficulty may be met by the very simple plan of blowing out at the surface of the water by means of a scum tap placed above the level of the furnace crowns. There was a scumming apparatus in this boiler, but the outlet was unfortunately connected with the blow-out at the bottom; whereas the two should have been distinct, and the outlet for the scumming apparatus above the level of the furnace crowns. Had this been the case, even though the scum tap had been left open, it could only have lowered the water to its own level, and being above the furnace crowns, could not have laid them bare; while the charge of blow-out taps at the bottom of boilers should be trusted solely to the head engineer, and the spanner kept by him under lock and key. These recommendations have already been given on a previous occasion in the report for September last, when referring to a precisely similar case of injury to furnace crowns.

Deficiency of Water.—This case was met with on the fireman's going to work on a Monday morning, when he found the boiler empty, the fires burning, and the furnace crowns red hot. The boiler had been cleaned out on the previous Saturday, and left on the following day with the fires banked up, the steam at a pressure of 9 lb. per square inch, and the water about 12 in. above the furnace crowns, when the attendant, on arriving on the Monday morning, found it in the condition just stated. It appears that the joint of the mudhole cover, placed at the bottom of the front end plate of the boiler, had frequently given trouble from leakage. It was made with yarn, while the faces of the cover and mouthpiece were very rough. There appeared, on examination, little room to doubt that the water had escaped through this joint, while this view is confirmed by the fact that near to this boiler there was an excavation for a new one, the ground of which was found by the attendant on his arrival in the morning to be quite wet, just as if the contents of the boiler had been drained into it. Had the joint surfaces of the cover and mouthpiece been properly got up and brought together metal to metal, the leakage just described could not have occurred.

Fracture.—This defect is, perhaps, one more pregnant with danger than any before met with in the inspections of this Association. It was found in one of three boilers, all of which were about 7 ft. 6 in. in diameter, connected together, and worked at a pressure of nearly 60 lb. on the square inch. The defect consisted of a crack which ran from rivet hole to rivet hole of the inner overlap of the plate, at a longitudinal seam of rivets near to the top of the boiler, the depth of the crack being half the thickness of the plate, while it extended to within a few inches of its entire width. Had it developed, as many cracks do, so as to lead to the rupture of the plate, the most serious consequences must have resulted. Not only would the shell of the boiler in question have been torn in pieces, but the adjoining boilers thrown from their seats, and possibly exploded from the shock, as has been found to be the case under similar circumstances. The boiler was but about three years old, so that it shows that entire examinations are important even for new boilers. . . . .

Referring to a disastrous explosion on board a vessel of a boiler of the engine employed to work the crane, on which Mr. Fletcher has the following with regard to some of the equipments. These, he says, were "defective both in the case of the man-hole and safety-valve. The man-hole, which measured 13 in. horizontally by 10 in. vertically, was not strengthened as it should have been with a substantial mouth-piece, nor even with a wrought iron ring, but had an ordinary internal cover, held up by one or two bolts suspended from arched bridges, notwithstanding the high working pressure and the lightness of the plates already described. The safety-valve arrangement was most objectionable. Every boiler should have two good valves, whereas this had but one, and that of a most dangerous class. It was fitted with a spiral spring, precisely similar to the one described in the report for May last, which proved, on being submitted to a most careful hydraulic test, to be so rigid as to prevent the valve rising sufficiently to admit of a free escape of steam. A compression of a little more than one-eighth of an inch raised the load upon the valve from a pressure of 80 lb. on the square inch to 200 lb., in addition to which the two nuts by which the spring was held down were loose, and neither guarded nor locked in any way, while the pillar bolts that carried them had neither stop-collars nor ferrules to prevent their being overscrewed, so that the valve could at any time be tampered with, or the engineman, in replacing the valve after taking it out, as he would have to do occasionally for cleaning, &c., might easily put on 100 lbs. more than the ordinary pressure without knowing it. Indeed, it was a matter of perfect haphazard whether he loaded the valve to 100 lb. or to 200 lb. There was only a turn of the nut between safety and explosion, or a single thread between life and death. Such a valve was, indeed, no safety valve at all, but only a delusion and a snare, totally unfit to be put on any boiler whatever, but more especially so on a small portable one, which, from the fact of these boilers not always being in the hands of the most skilled attendants, should be the more carefully contrived for simplicity and safety. . . .

The cause of the explosion was made a matter of the most searching investigation by the coroner, who indefatigably pursued the inquiry for three entire days. Neither the makers of the boiler, however, nor the intermediate party who had sold it to the shipowners, were present at the inquest, both excusing themselves on the plea of illness, but the makers were represented by their lawyer as well as by their manager. In their defence they attempted, as is usual in these cases, to throw all the blame upon the poor engineman who had been killed by the explosion. The legal gentleman tried hard to prove that the engineman had allowed the furnace tube to be laid bare and overheated, through neglecting his feed, and that water must then have been dashed upon the hot plates, either from the sudden introduction of the feed, or starting of the engine, in consequence of which an excessive and uncontrollable pressure of steam had been instantaneously generated, which burst the boiler into fragments with the force of an ignited charge of gunpowder. It may be questioned whether such consequences would have resulted even if the furnace tube had been overheated as supposed, since the feed water was pumped into the boiler at the bottom, or nearly so, so that it could only have submerged the furnace tube little by little as it rose and cooled it down gradually, which could not, it is thought, have produced any rapid generation of steam. In support of this a case mentioned in a previous report may be referred to, in which water was pumped into a red hot boiler without having any other effect than so straining the seams from violent contraction that they leaked like a sieve, and the water ran out of the boiler faster than the engineman could pump it in, which was the first intimation of anything being wrong. These remarks, however, must not be misunderstood. It is not by any means intended to countenance the introduction of the feed into boilers after the furnace crowns have been laid bare and overheated: under such circumstances the fire should be withdrawn as soon as practicable, and the furnaces allowed to cool down gradually. The question raised is whether the contact of water with hot plates would instantaneously generate such a sudden pressure of steam as to burst the outer shell. This inquiry is a most important one, especially since so many explosions are popularly attributed to this cause. It deserves to be submitted to the test of practical experiment as the only satisfactory way of determining the question.* But whether the legal gentleman's hypothesis be correct or not, it will be seen on referring to the facts of the case, that it does not apply in the present instance. It is true that the furnace tube was slightly discoloured a little below the water line, for a belt of about 12 inches in width, but at the same time the soot remained on the inner side of the furnace, and the plates were not in any way distorted nor the seams opened, while the two transverse water tubes, which passed through the middle of the flame, were entirely unaffected either at their plates or seams of rivets, which, it is thought, is scarcely consistent with the view of the furnace tube having been overheated, and at the same time submitted to a high pressure of steam. In addition to this, it was given in evidence that the engine was not working at the moment of the explosion, but standing during the dinner hour, so that the feed was not being pumped in, as supposed, or the water agitated by the working of the engine; while, in addition, there appears to have been plenty of water in the boiler at the time, since, although the glass tube was broken, the water was up to the lower tap but about ten minutes before the explosion, when at the same time the attendant was seen to screw down the safety-valve, with a brisk fire burning, and the engine, as already stated, standing still.

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* At the meeting of the committee at which this report was read the propriety of attempting to determine this question by actual experiment was discussed, and it was unanimously agreed that the subject was of sufficient importance to justify this course, and, therefore, it was resolved that a boiler should be purchased expressly for the purpose of practical test.

From this it will be seen that the assumption of the legal gentleman, that water was dashed on to the furnace tube when overheated, is quite unsupported by the evidence. The manager differed from the legal gentleman just quoted, and did not attribute the explosion to shortness of water, but to excessive pressure of steam in consequence of the attendant's having screwed down the safety-valve; but did not consider it improper to turn out such safety-valves without stop ferules, so as to prevent their being over-loaded in this way, and thought them quite as safe as any others. He also considered the boiler to be stronger at the unguarded manhole than at the seams of rivets, that it would have stood a test of 500 lb. on the square inch, and that there must have been about that pressure of steam in it at the time of the explosion. In short, the boiler was a good one and suitably equipped, but the attendant was either careless or ignorant, and nothing could have prevented the explosion. Two scientific witnesses, as well as myself, gave evidence at the inquest. One of them, who was for years the chief engineer of the Great Britain steamship, and subsequently of the Great Eastern, thought the boiler, fitted with such a safety-valve, might fairly be likened, from its murderous propensities, to one of the "infernal machines" of French notoriety; and he had, shortly after the explosion occurred, on examining a similar boiler made by the same makers, seen the engineman screwing down the safety-valve, though with steam at a pressure of 90 lb. per square inch; and he mentioned this fact to show the unguarded nature of these safety-valves, the ease with which they could be tampered with, and the impropriety of turning out boilers with a single one only. The three scientific witnesses arrived unanimously at the conclusion that the explosion did not arise from shortness of water, but from the weakness of the boiler at the unguarded manhole, in conjunction with the highly defective safety-valve; or, in other words, from simple pressure of steam, which the safety-valve was too defective to relieve and the boiler too weak to withstand. . . . .

Referring to an explosion of a Cornish boiler, Mr. Fletcher, on the subject of safety-valves, says that these frequently commence to blow off at a few pounds below the pressure they should do according to calculation, on account of the faces of the valve and seating not accurately fitting one another on their inner edge, which may arise either from the two faces not being at precisely the same angle, or from want of grinding to a true surface. It does not follow that a valve should leak under these circumstances, as it may be tight at the outer edge of the seat, though not at the inner one; but in consequence of this inaccuracy, the steam insinuates itself between the two faces, and thus operating on a larger area than that due to the accepted diameter of the valve, lifts it at a slightly lower pressure of steam than it otherwise would. Safety-valves with wide bearing surfaces are more liable to this inaccuracy than those with narrow ones. . . .

Of the recklessness of the engineman there can be no question, and it cost him his life; but if the whole truth must be spoken with regard to this explosion, more must be said; in the first place, with regard to the incompetence of the attendant, and, in the second, the inefficiency of the boiler and its fittings. Culpable as the engineman clearly was, there are plenty of men to be had who are too well educated and too reliable to be so foolhardy as to blow either themselves or their masters' boilers to pieces; and if it be objected that the employment of a superior class of men would necessitate a higher rate of wages, and thus increase the working expenses, it is thought that this may be fairly answered by contrasting the small outlay necessary to meet the rise of wages with the expense of such a catastrophe as the present, which laid the works in ruins. False economy is the cause of many explosions. With regard to the boiler and its fittings: had these been all they might have been, the explosion would not have happened. Every boiler should have a duplicate safety-valve. Had one of these been of the description adapted for blowing-off when the water sinks below its proper level, and which are fitted with an internal weight, the attendant could not have gagged it without letting the steam down, taking off the manhole lid, and getting inside the boiler, which he had no opportunity of doing; while, if the second safety-valve had been of the external dead-weight class, a few bricks added to the proper load would have had but little effect upon it. The difference between overloading a dead-weight or a lever safety-valve must be obvious at a glance. Thus:—The proportions of the lever in the present instance were thirteen to one, so that every pound hung on to the end put thirteen upon the valve, and the three bricks added 27 lb.

per square inch, while with a dead-weight valve of equal diameter three bricks would only have added 2 lb., so that it would have taken thirty-nine bricks to do as much mischief with the dead-weight valve as three did with the lever one. Also three bricks may easily be tied on to the end of a safety-valve lever by a piece of string, as they were in the present instance, but it is not so easy to pile thirty-nine on to the dead-weight valve, especially if carried up through the roof of the boiler-house, as these valves frequently are, so as to be in nobody's reach without a ladder, and at the same time conspicuous to all. Both these dead-weight and low-water safety valves have been frequently referred to on previous occasions; hundreds are at work satisfactorily in different parts of the country, and many of the explosions met with would have been prevented by their adoption. With regard to the boiler itself, it may be added that the furnace tube was not strengthened either with flanged seams, encircling hoops, or other approved means; and had these precautions been adopted the boiler would not have burst as it did, at a pressure of 110 lb. per square inch, while there is reason to doubt, judging from the direction of the collapse, whether the furnace tube was truly cylindrical, which it is most important should always be the case. Important, however, as these considerations are, the construction of the furnace tube has not so immediate a bearing upon this explosion as the question of fittings referred to above.

In conclusion, while there is no question as to the culpable recklessness of the engineman, and that it proved the immediate cause of the explosion, by leading to an excessive pressure of steam, yet it must be added that a well-made boiler, equipped as recommended above, and as many are, could not without difficulty have been blown up by the attendant, even if he desired to do so, while there are plenty of suitable men to be had, who would not blow up a boiler if they could. Superior attendants and superior boilers would prevent the recurrence of such explosions as the present."

(*b*) *Notes from the Annual Report of the Midland Boiler Association.*

No. 1. *January* 1*st*, 1866. *none injured.*

"This was a locomotive boiler which had been shunting, and was standing with steam up near a platform. All but the fire-box was blown away, the main portion being thrown a distance of 400 yards. The explosion took place at a longitudinal seam of the barrel. The engine had been working at 110 lb., and had been proved by hydraulic test above that pressure a short time before. The cause was grooving at the joint which gave way, which it was considered had gone on very rapidly, as it was not discovered when examined and tested.

No. 2. (Fig. 25.) *January 2d,* 1866. 2 *injured.*

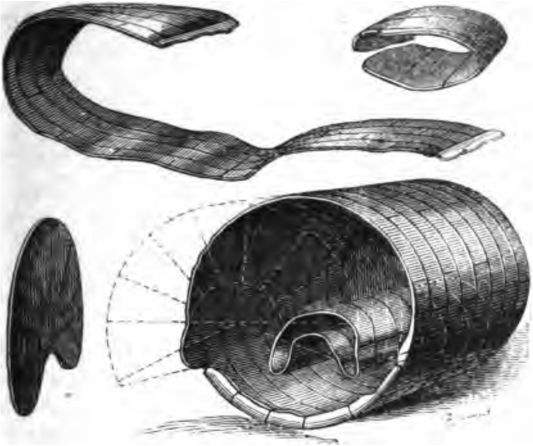


Fig. 25.

The boiler was of the type known as Butterly. It was 26 ft. 6 in. long and 9 ft. diameter. The wagon-shaped top to the fireplace was 8 ft. 6 in. long, and was attached to the bell mouth of the internal tube, which then continued circular to the back of the boiler. The tube was 3 ft. 6 in. diameter. All the plates were about $\frac{7}{16}$ in. thick, and although the boiler was an old one, they were no where reduced in thickness by wear. The usual pressure of steam was 18 lb., and a self-registering gauge showed that at the time of the explosion it did not exceed 20 lb. The boiler was fitted with float, alarm whistle, glass gauge, safety-valve, and self-acting feed apparatus, and the even water mark, about 1 ft. above the top of the tube, showed the latter had worked regularly. There was a fusible plug which was placed over the firegrate, and appeared to have commenced to give way.

The effect of the explosion was, that the top of the firegrate on the right side had rent longitudinally, and the upper part of the shell consisting of four rings of plates, and also the top of the fireplace, opened out and blew away to a considerable distance.

The front end became disengaged, and also blew away. The bell-mouth of the tube was detached and blown to the front, and the tube which remained in the back part of the shell was collapsed upwards so completely that the bottom nearly touched the top, which latter retained its original shape.

There were a few signs of shortness of water, but nothing certain or trustworthy.

The cause of the explosion was most likely the intrinsic weakness of boilers of this shape, especially over the fire, where the top is only retained in its shape by numerous stays. The boiler had been very frequently repaired at this, the weakest place, and its strength had been thus so reduced as to make it unable to bear even a few pounds more than the ordinary working pressure.

The whistle was found to have been gagged by hemp, carefully inserted, so that there is ground for supposing there had been intentional unfair usage.

No. 3. (Fig. 26.) *January 8th*, 1866. 1 *killed*, 1 *injured*.

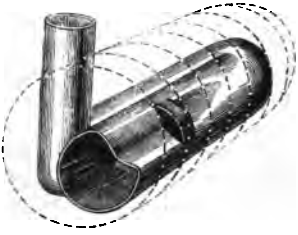


Fig. 26.

The boiler was of the ordinary type used in small steam-boats, and consisted of a cylindrical shell, about 5 ft. diameter and 20 ft. long, with flat front and hemispherical back, with an internal cylindrical fireplace, with a flue leading nearly to the back of the boiler, and returning nearly to the front, and then passing up through the steam-space and through the top of the shell to the chimney. The usual working pressure was 14 lb.

The effect of the explosion was, that a rent was made in the angle iron just within the fireplace, and the torn plate was bent downwards. There were altogether three rents in the tube over the fire, as a small band was held in its place by a stay from the tube to the shell. The escaping contents scalded those near, but no damage was done to anything but the boiler.

The cause was stated to be shortness of water. There was no gauge for ascertaining the height of the water.

No. 4. *January* 17*th*, 1866. 1 *injured.*

This was a boiler of the Cornish type, but no details have been obtained.

No. 5. *January* 9*th*, 1866. 1 *killed.*

This boiler was of the Cornish type, 28 ft. long, 6 ft. 6 in. diameter, with one tube 3-6 diameter, made of ⅜ in. plates, and worked at 45 lb. The fittings were efficient. There was no sign of overheating.

The result of the explosion was that the tube collapsed in an inclined direction.

The cause was the weakness of the tube of such large diameter, which, without strengthening rings, was unable to resist the ordinary working pressure.

The appearance after explosion was nearly the same as that shown in sketch given at No. 12 explosion (fig. 31).

No. 6. (Fig. 27.) *January* 13*th*, 1866. 4 *killed*, 4 *injured.*

This was a two-tube Cornish boiler, 22 ft. 3 in. long, and 7 ft. 7 in. diameter, made of ⅜ in. plates. The tubes were 2 ft. 7 in. diameter, made of ⅜ in. plates. The boiler was fitted with glass gauge and three gauge cocks and two safety-valves loaded to 40 lb.

There was no sign of shortness of water.

The result of the explosion was, that about 8 ft. of the back portion of the shell had torn off and blown away, leaving the tubes and ends intact.

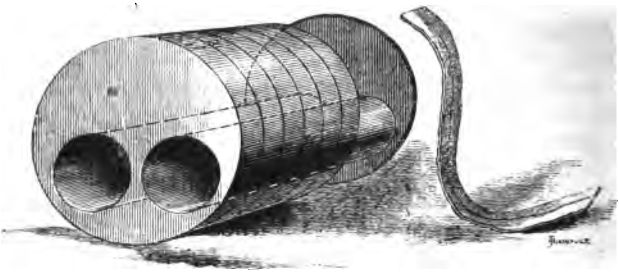


Fig. 27.

The cause of the explosion was considered to be excessive pressure, but how accumulated did not transpire.

It is most natural to expect that there must have been corrosion under the bottom to cause the first rent.

No. 7. (Fig. 28.) *January* 18*th*, 1866. 1 *killed*, 2 *injured.*

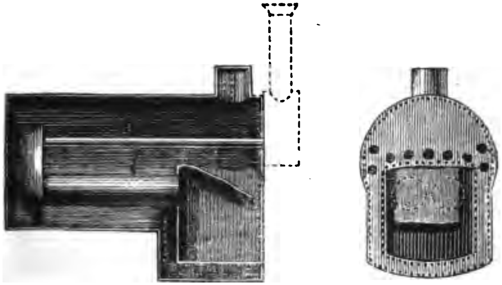


Fig. 28.

This boiler was of the agricultural type, 8 ft. 2 in. long, 3 ft. 6 in. diameter in the barrel, and made of $\frac{5}{16}$ in. plates. There was an internal fire-box, 2 ft. 4 in. wide, 2 ft. 4 in. high, and 2 ft. 10 in. deep. From the back of this fire-box two 12 in. tubes passed to an internal chamber at the back of the barrel. From this again passed nine $3\frac{3}{4}$ in. tubes to an exterior smoke-box fixed over the fire door. The boiler was fitted with one spring safety-valve, which was screwed down tight, but had no pressure gauge. The front plate was intended to be bolted on so that the fire-box and tubes could be taken out for cleaning, but it had been riveted, leaving no means of cleaning, and it was nearly full of scurf.

The effect of the explosion was, that the crown plate of fire-box, which was too flat and unstrengthened, rent at the front and along both top edges, and was driven into the fire. The boiler was thrown backwards and reared against a wall, resting on the front right-hand corner.

The cause of the explosion was the very dirty state, allowing of overheating where the water was not in proper contact with the plates, as the construction was so defective as not to admit of proper cleaning. The mountings were insufficient for the proper protection of the boiler.

No. 8. (Fig. 29.) *January 29th*, 1866. 1 *killed*, 3 *injured.*

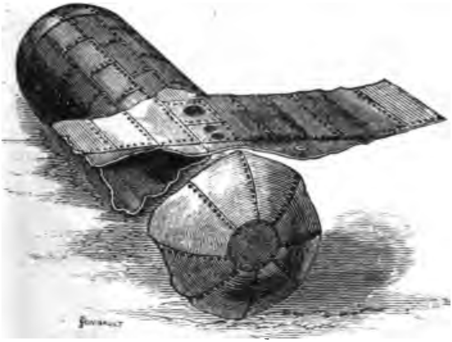


Fig. 29.

This was a plain cylinder boiler, with hemispherical ends, 30 ft. long and 6 ft. diameter, made of $\frac{3}{8}$ in. plates, and worked at a pressure of 30 lb. It was the second from the engine in a bed of fuse, and had been at work three years, then remained idle for eight years, working again fourteen years. The boiler was mounted with two safety-valves $3\frac{7}{8}$ and 4 in. diameter, a float, and alarm whistle. The boiler had been more than once repaired over the fire with several new plates. One seam over the fire had been observed to leak about a week before the explosio but not seriously, and had been caulked. The boiler had just been started after cleaning. Six months before explosion. the boiler had been tested to 69 lb.

The effect of the explosion was that about 5 ft. of the front end of the boiler opened out flat, and was thrown to the rear about 60 yards; the front hemispherical end was liberated and thrown 20 yards also to the rear and right hand. The back part of the boiler was thrown in a mass, and, after bounding twice, lodged at a distance of 230 yards.

The cause of the explosion appeared to be from the failure of a seam over the fireplace in a plate deteriorated by age, and overheated through a deposit of scurf and mud.

No. 9. (Fig. 30.) *February 7th,* 1866. 1 *killed,* 4 *injured.*

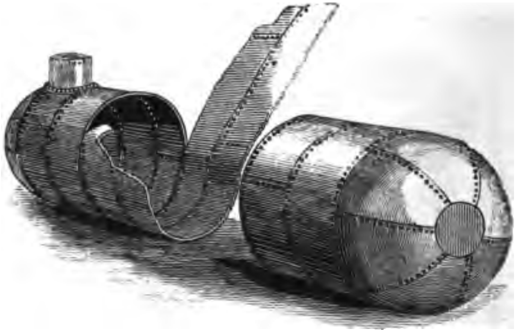


Fig. 30.

This was a plain cylindrical boiler, with hemispherical ends, 23 ft. long and 5 ft. diameter, made of ⅜ in. (full) plates, and worked at 50 lb. pressure. There was a small dome at the back. It was set so as to be fired under the bottom, if required, but the grate was seldom used. The principal heat was supplied from a mill furnace, the neck of which was at the left hand of the back, and the flame was carried by a wheel flue round the front of the boiler to the stack on the right-hand side of the back. The boiler was fitted with a 4¾ in. safety-valve, and also a float, but it was suspected that the latter had broken from the rod.

The effects of the explosion were, that a horizontal seam about the middle of the left-hand side had given way, and the upper portion of the third and fourth rings of plates had spread out like a lid without being detached from the boiler. The front end became detached, and was thrown some distance to the front.

The cause of the explosion was, that the left side of the boiler became overheated, and so much softened, that it first bulged outwards with the ordinary working pressure, and then rent open. The overheating was most likely the result of shortness of water, but it might possibly have been in consequence of the intense heat of a mill furnace impinging on a small area so near the water-line, leading to such rapid ebullition as to prevent sufficient contact of the water to keep the plates cool.

No. 10. *February* 14*th*, 1866. 1 *injured.*

This was a railway locomotive, and it exploded while standing in a shed, but no particulars have been obtained.

No. 11. *February* 26*th*, 1866. 1 *injured.*

This was a marine boiler in a small tug boat, but no details have been obtained.

No. 12. (Fig. 31.) *February* 26*th*, 1866. 1 *injured.*

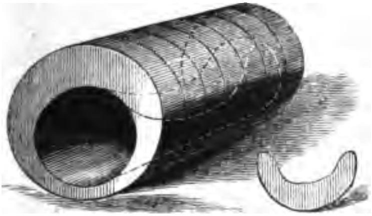


Fig. 31.

This boiler was of the Cornish type, 21 ft. long, 5 ft. diameter, with one tube 2 ft. 11 in. in diameter, made of plates $\frac{3}{8}$ in. thick. There were no strengthening rings on the tube. The boiler was second hand, and had only worked a part of a day at its new position when it exploded.

The pressure shortly before the explosion was 64 lbs. The tube collapsed, but the shell remained uninjured.

The cause of the explosion was the weakness of the tube without strengthening rings.

No. 13. *March 5th*, 1866. 7 *injured.*

This was a Cornish boiler worked at 27 lbs., but as the boiler was not injured, it is only noticed as an explosion, because of the imprudence of placing fittings in such dangerous positions. The boiler was beneath a work-room, and the lever of the safety-valve became displaced, allowing the valve to blow out, and the escaping steam rushed into the room above and scalded seven men very badly.

No. 14. (Fig. 32.) *March 3d*, 1866. 1 *killed.*

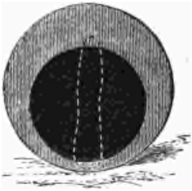


Fig. 32.

This was a Cornish boiler, 31 ft. 9 in. long, and 5 ft. 9 in. diameter, with one tube 3 ft. 8 in. diameter, made of ⅜-in. plates, worked at 40 lbs. pressure.

The tube had been repaired with a bolted patch on the left side the day before the explosion, and it is presumed it was slightly out of the circular shape.

The effect of the explosion was that the tube collapsed sideways, the top being thrown up above its proper height. There was no evidence of shortness of water.

The cause of the explosion was that the tube was too weak to sustain the ordinary working pressure, there being none of the strengthening rings found to be so essential to insure safety.

No. 15. *March 6th*, 1866. 1 *killed.*

This was a boiler with two internal fireplaces connected into one flue at the back.

The effect of the explosion was that the crowns of both furnaces were collapsed and slightly rent, and the escaping steam and water scalded the attendant.

The cause was that the water was 8 or 9 in. below its proper level, allowing the furnace-crowns to become overheated and unable to bear the working pressure.

Each furnace had been fitted with a fusible plug, but they proved inefficient.

No. 16. (Fig. 33.) *March* 13*th*, 1866. 1 *killed*, 1 *injured.*

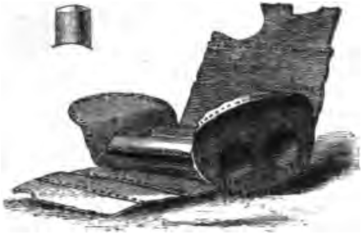


Fig. 33.

This was a very small boiler, 8 ft. long, and 3 ft. 2½ in. diameter, with two small tubes through. It was fired externally. There was a dome on the top.

The effect of the explosion was, that the dome was blown off, and, the rents continuing, the top opened out on each side, and the upper portion of both back and front were bent back.

The cause of the explosion was, that the dome cut away the whole of the top plate, and so much reduced the strength that it would not bear the ordinary working pressure.

No. 17. (Fig. 34.) *March* 19*th*, 1866. *none injured.*

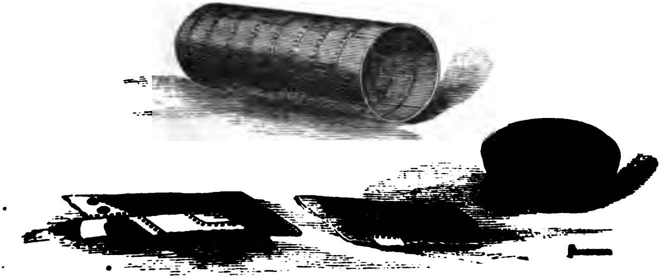


Fig. 34.

This was a plain cylinder boiler, 36 ft. long, 5 ft. 6 in. diameter, and worked at a pressure of 60 lbs. It had frequently been repaired over the fire, so that the longitudinal seams ran for several plates without break of joint. A patch had been put on a few days before explosion, and, as the rivet-holes had badly fitted, there had been much strain caused by drifting, and the rivets were much distorted.

The effect of the explosion was that a longitudinal seam gave way over the fire, when two rings of plates opened out, rending the transverse seams at each side until completely separated, and fell in two parts at a distance of about 100 yards in front of the boiler. The front end was liberated, and fell in one piece about 100 yards beyond the two pieces of the shell. The main body of the boiler was driven back a few yards, and rolled over so as to be upside down, but was little injured.

The cause of the explosion was the frequent and badly executed repair over the fireplace, which so weakened the structure as to make it unable to bear the very high ordinary pressure. This frequent repair over the fireplace had been made necessary by very hard firing and deposits of scurf from muddy water, preventing the proper contact of the water with the plates.

No. 18. *March* 22*d*, 1866. 1 *killed.*

This was a small boiler to supply steam for some steam winches on board a steamboat, and exploded through the overheating of the upper tubes through shortness of water, or from over-pressure in consequence of having only one safety-valve.

No. 19. (Fig. 35.) *March* 27*th*, 1866. 2 *killed*, 18 *injured.*

This boiler was of the Cornish type, 24 ft. 6 in. long, 6 ft. 6 in. diameter. The tubes were 2 ft. 6 in. diameter, made of $\frac{3}{8}$-in. plates. The working pressure was 54 lbs. It was fitted with a steam gauge, blow-off cock, a $1\frac{1}{2}$-in. dead weight safety-valve, loaded to 54 lbs., and a $4\frac{3}{8}$-in. lever safety-valve, loaded to 62 lbs. The boiler had been at work about five years.

The effect of the explosion was that nearly the whole of the two back rings of the shell were torn off and opened out, and the boiler was turned partly round, and moved upon its seat sideways and forwards.

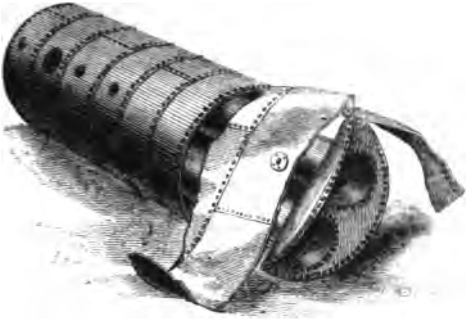


Fig. 35.

The cause of the explosion was most extensive corrosion at the under side of the back of the shell, where the first rent took place, caused by the leaking of the joints and seams.

No. 20. (Fig. 36.) *April 4th*, 1866. 5 *killed*, 4 *injured*.

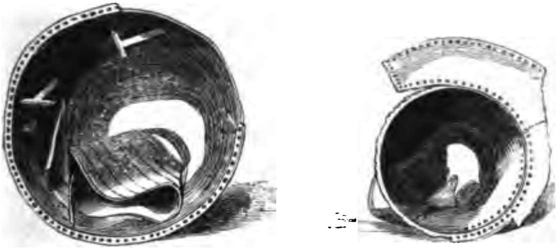


Fig. 36.

This was a Cornish boiler, 30 ft. long, and 7 ft. diameter, with one tube slightly oval about 4 ft. diameter, made of $\frac{7}{16}$-in. plates, and worked at 43 lbs. pressure. The boiler was fitted with a $3\frac{1}{2}$-inch safety-valve, which is much too small for such a boiler. There was also a glass water gauge, two gauge cocks, and a pressure gauge.

The effect of the explosion was that the tube collapsed from end to end. The front end was blown out with a short length of the tube attached, and was driven against a wall about 30 yards to the front. The main body of the shell, and the back end, with the collapsed tube within it, were driven back against another wall, about the same distance away. The explosion was so violent that very great damage was done to the surrounding property. There was no evidence of shortness of water.

The cause of the explosion was the weakness of the tube of so large a diameter, without strengthening rings, which made it unable to bear the ordinary working pressure. It is very probable, however, that at the time of the explosion, the pressure was considerably more than usual during the sudden stoppage of the engine, and the confusion caused by a man becoming entangled in the machinery.

No. 21. *April* 10*th*, 1866. 1 *killed.*

This was a plain cylinder boiler, with hemispherical ends, 34 ft. long and 5 ft. diameter, made of $\frac{3}{8}$ in. plates placed lengthways, and worked at 33 lb. pressure. It was mounted with the usual fittings, and was not corroded.

The explosion took place at a seam in the front part of the bottom of the boiler just over the fire. This rupture allowed the sides to expand, until the boiler was completely destroyed and torn into seven pieces.

The cause of the explosion was supposed to be the defective state of the seams over the fire, which, being placed longitudinally, were in the weakest position.

No. 22. *April* 26*th*, 1866. 2 *killed*, 2 *injured.*

This was a small internally fired boiler, 5 ft. high, 2 ft. 4 in. diameter, and was intended to work at 70 lb. The fittings were defective, the spiral spring of the safety-valve being most easily altered so as to cause over-pressure. The manhole was not strengthened by any ring, and the first rents commenced at that point.

The cause of the explosion was over-pressure and defective construction.

The sketch at No. 57 explosion in this year is of a similar boiler, which exploded from nearly similar causes.

No. 23. (Fig. 37.) *April 21st*, 1866. *none injured.*

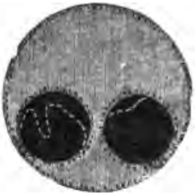


Fig. 37.

This was a Cornish boiler, 15 ft. long, 6 ft. diameter, with two tubes 1 ft. 8 in. diameter, made of $\frac{3}{8}$ in. plates, and worked at 40 lb. pressure. The heat was supplied by two furnaces, one of which played into each tube.

The effect of the explosion was, that the left-hand tube collapsed, and tore away from the angle-iron in the front plate, and allowed the contents to issue violently and scattered the brickwork, but the boiler was not disturbed.

The cause of the explosion was shortness of water, as the collapsed tube had evidently been over-heated.

No 24. (Fig. 38.) *May 13th*, 1866. *none injured.*

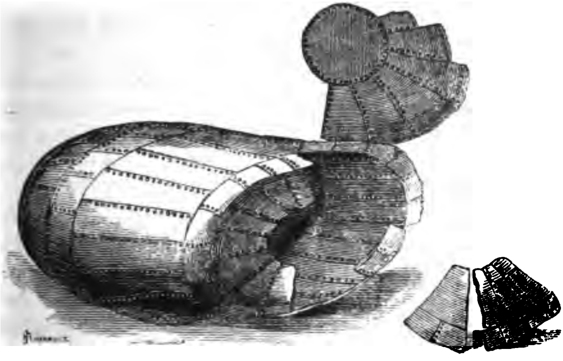


Fig. 38.

This was an old-fashioned balloon or haystack boiler, about 16 ft. diameter, made of $\frac{5}{16}$ in. plate, and worked at very little above atmospheric pressure.

The boiler was chiefly used to store water during the time another boiler by the side of it was emptied. When the water was required to refill the other boiler, a fire was lighted under the balloon, and sufficient steam generated to drive the water from it into the other boiler. The safety-valve never being used, it had become fast, and as a little more steam than usual had accumulated, the bottom gave way, and the reaction of the issuing contents made the boiler rise from its seat, and it fell on its side at some distance away, flattened by the fall.

No. 25. (Fig. 39.) *May 25th*, 1866. *none injured.*

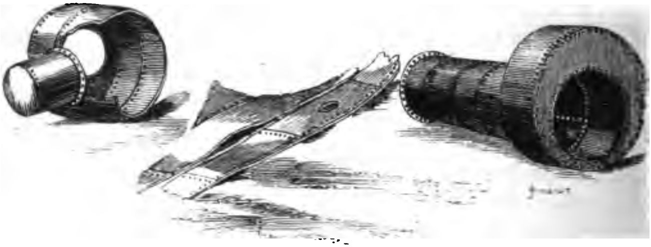


Fig. 39.

This was a Cornish boiler, 15 ft. long and 4 ft. 6 in. diameter, with one taper tube, 2 ft. 9 in. diameter in front and 2 ft. diameter at back, made of $\frac{3}{8}$ in. plates, and worked at a pressure of 30 or 40 lb. The boiler rested on two walls forming the bottom flue. There was a safety-valve, a glass water-gauge, a pressure gauge, and two fusible plugs upon the tube. There was nothing to show shortness of water or over-pressure.

The effect of the explosion was, that two longitudinal rents took place on the under side of the shell, allowing two strips, forming the central part of the shell, to open out by the continuation of the fracture, until they were blown to a considerable distance. The tube, with the front end, and one ring of the shell were thrown to the front, while the back end was thrown to the rear, the smallest end of the tube having torn away from the back.

The cause of the explosion was, that the shell was deeply corroded where it rested on the side walls of the bottom flue, and the strength of the boiler was thereby so much reduced, that it was unable to bear the ordinary working pressure.

No. 26. (Fig. 40.) *May* 26*th*, 1866. 1 *killed.*

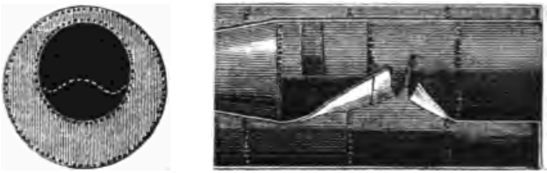


Fig. 40.

This was a Cornish boiler, 24 ft. 6 in. long, and 5 ft. diameter, with one taper tube, slightly oval in the front, 2 ft. 8 in. diameter, and 2 ft. diameter at the back; made of $\frac{3}{8}$ in. plates. The boiler was fitted with a glass water-gauge, and also a float, a self-acting feed apparatus, and a safety-valve loaded to 52 lb., and also a mercury gauge.

The effect of the explosion was, that the tube collapsed over the fire, a rent taking place in the second ring of plates. The issuing steam and water caused the death of a man in front, but the shell of the boiler was not injured or moved.

The cause of the explosion was shortness of water, and as the glass gauge was set unusually low, the man in charge may have been deceived. The oval shape of the fire-place, and the laminated iron, as shown in the fracture, rendered the tube peculiarly liable to collapse.

No. 27. *May* 26*th*, 1866. 1 *killed.*

This was a plain cylinder boiler, 34 ft. long, 5 ft. diameter, made of $\frac{3}{8}$ in. plates, and worked at 45 lb. pressure. It was fitted with two 5 in. safety-valves and 2 floats.

The effect of the explosion was that the boiler was torn in two pieces, that were thrown to a considerable distance. The first rent had taken place immediately over the fire.

The cause of the explosion was the weakening of the shell by the frequent repair over the fire, and this repair was rendered necessary by the deposit from the muddy water preventing proper contact of the water with the plates.

No. 28. *May 27th*, 1866. 1 *killed.*

This was a plain cylinder boiler, 32 ft. long, 6 ft. diameter, made of $\frac{3}{8}$ in. plates, and worked at a pressure of 35 lb. It was fitted with two safety-valves, two floats, and two alarm whistles.

The effect of the explosion was, that the boiler was lifted from its seat, and one end was separated and thrown to a considerable distance.

The cause of the explosion was weakening of the shell from repair a few days before, and perhaps over-pressure, as the gauge was found some time after, and indicated that the pressure had at some time exceeded 80 lb.

No. 29. *May 28th*, 1866. 1 *killed*, 4 *injured.*

This was a Cornish boiler, 30 ft. 8 in. long, 6 ft. 8 in. diameter, with one tube, 4 ft. diameter, made of $\frac{7}{16}$ in. plates, and worked at 40 lb. pressure.

The effect of the explosion was, that the tube collapsed and rent, and the issuing steam and water scalded those near.

The cause of the explosion was that the tube was too weak to bear the ordinary working pressure, it having no strengthening rings.

No. 30. (Fig. 41.) *May 31st*, 1866. 1 *killed*, 1 *injured.*

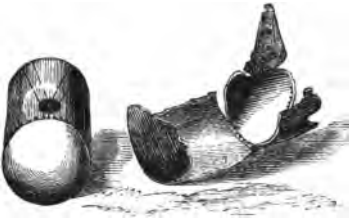


Fig. 41.

This was a plain cylindrical boiler, with dished ends, and only 4 feet 2 in. long, and 2 ft. 6 in. diameter, and made of $\frac{1}{4}$ in. plates. The boiler was most inefficiently mounted, the safety-valve was only $1\frac{5}{8}$ in. diameter, and of such faulty construction that it would not open under a pressure of 162 lb. There was no steam-gauge or float, and the gauge cocks were defective. There was no means of putting water in the boiler when there was a pressure of steam. The manhole was very large for so small a boiler.

The effect of the explosion was, that four rents starting from the manhole continued along the top of the boiler and round the end seams. A tongue-shaped strip of the top plate was attached to the back end plate; two strips about a foot wide on either side were blown away. The boiler had been turned nearly round in its flight, and fell with the back about 12 ft. from the original position of the front.

The cause of the explosion was, that the boiler was worked until it was nearly dry, and during a temporary stoppage of the engine an accumulation of steam caused a greater pressure than the boiler could bear. The large manhole being the weakest place, the rent commenced there.

No. 31. *June 7th*, 1866. *None injured.*

This was a marine boiler in a tug boat.

The effect of the explosion was, the boiler was blown completely out of the vessel, and the greater part of it fell into the water, and a large piece alighted on a crowded quay, but without doing any damage.

The cause of the explosion was supposed to be over-pressure during a temporary stoppage of the engine.

No. 32. (Fig. 42.) *June 11th*, 1866. *2 injured.*

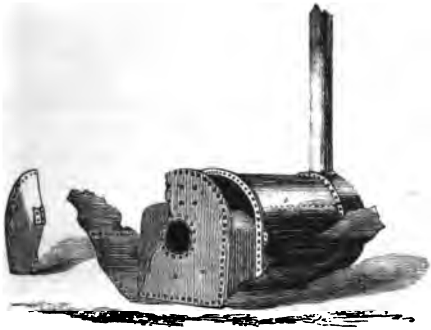


Fig. 42.

This was a portable boiler of the agricultural type, of about 7 horse power. The barrel of the boiler was 6 ft. 1 in. long, 2 ft. 5 in. diameter; the fire-box end was 3 ft. wide, and 2 ft. 4 in. deep; the fire-box was 2 ft. 5½ in. wide, and 2 ft. 7 in. high, and 1 ft. 9½ in. deep, with twenty-three tubes passing from it through the barrel to the smoke-box and chimney. The boiler was fitted with a two-inch safety-valve, which was intended to blow at 45 lb., but as there was no ferrule, it is supposed to have been screwed down to a much greater pressure.

The effect of the explosion was that the upper portion of the shell over the fire-box rent through the manhole, and allowed the shell to open out and fall on each side. A large portion of the front plate was also torn off.

The cause of the explosion was the weakness of the manhole, which was not strengthened by any ring, and also excessive pressure from want of proper safety-valve.

No. 33. *June* 11*th*, 1866. 1 *killed.*

This was a Cornish boiler, 36 ft. 6 in. long, and 6 ft. diameter, made of ⅜ in. plates, and worked at 45 lb. pressure.

The effect of the explosion was that the tube collapsed and rent, and the issuing contents caused the death of the attendant.

The cause of the explosion was the weakness of the tube of such large diameter, which was unable to bear the ordinary working pressure, having no strengthening rings.

No. 34. *June* 19*th*, 1866. 2 *killed*, 4 *injured.*

This was a railway locomotive, made of ½ in. plates, and worked at 140 lb. pressure.

The explosion occurred at the left-hand side of the ring of plates in the barrel next the fire-box and below the foot-plate. The rent tore along the edge of the lap and into the next ring of plates. The reaction of the issuing contents threw the engine off the rails.

The cause of the explosion was partial corrosion at the point of rupture and strain of the plates, as the boiler itself formed part of the frame of the engine.

No. 35. *June* 26*th*, 1866. 2 *injured.*

This was a new railway locomotive, and was being tried for the first *time* when the funnel came in contact with a bridge, and the dome was also torn off.

The cause of the explosion was, therefore, extraneous to anything belonging to the construction of the boiler.

No. 36. *June 29th*, 1866. *None injured.*

No details have been obtained.

No. 37. *Jnly 2d*, 1866. 4 *killed.*

This was a plain cylindrical boiler, 30 ft. long and 6ft. diameter, made of $\frac{3}{8}$ in. plates, and worked at 28 lb. pressure. The boiler had been repaired, a short time before the explosion, with five new plates.

The effect of the explosion was that the boiler was torn up into several pieces, but the main portion remained flattened out on the seating, while some smaller pieces were sent 250 yards away, but as the fragments were cleared away and cut up before proper examination could be made, it was impossible to trace out the first rent.

The cause of the explosion was most likely the deterioration of the boiler, and its frequent repair over the fireplace during its nine years of working.

No. 38. *June 12th*, 1866. 4 *injured.*

This was an old-fashioned elephant boiler, 20 ft. long, and 4 ft. diameter, made of $\frac{3}{8}$-in. plates, and worked at low pressure. The bottom shell had a tube through its whole length.

The effect of the explosion was, that a rent took place in the lower part of the fireplace, and extended along the bottom, and the reaction of the issuing contents caused the top to rear up.

The cause of the explosion was supposed to be that the bottom plates were worn too thin to bear the ordinary pressure.

No. 39. *July 4th*, 1866. *none injured.*

This was a Cornish boiler externally fired, 30 ft. long, and 6 ft. diameter, with two internal tubes made of $\frac{3}{8}$-in. plates, and worked at 40 lbs. pressure.

The effect of the explosion, although not violent, was, that the second seam over the fire gave way, and the plate sank down upon the fire.

The cause of the explosion was the deterioration of the seams over the fire, most likely in consequence of the deposit of scurf which could not be properly cleared off owing to the internal tubes.

No. 40. *July* 14*th*, 1866. *none injured.*

This was a boiler with two internal furnaces, 9 ft. 6 in. long, and 2 ft. 11 in. diameter, made of $\frac{3}{8}$-in. plates, uniting into one tube beyond.

The effect of the explosion was, that the furnace-crown collapsed near the front of the boiler.

The cause of the explosion was, that there was an extra weight upon the safety-valve, and the steam-valve was left closed, so that more pressure accumulated than the boiler could bear.

No. 41. *July* 23*d*, 1866. 3 *injured.*

This was a rag boiler, and was not used for the generation of steam. It was a plain cylinder, with hemispherical ends, about 16 ft. long and 7 ft. diameter. There was a neck at each end upon which the boiler revolved, and through one of these the steam was admitted to a pressure of 30 lbs., in order to assist in clearing the rags. There was a large manhole for filling and emptying.

The effect of the explosion was, that the boiler rent in the middle, and each half was blown to some distance.

The cause of the explosion was, that the manhole was so large, that the strength of the boiler was too much reduced, and the constant strain of revolving caused a central seam to give way at the ordinary pressure.

The sketch to No. 63 is of a similar boiler.

No. 42. (Fig. 43.) *July* 28*th*, 1866. 2 *killed*, 7 *injured.*

This was a boiler 36 ft. 6 in. long, and 8 ft. 9 in. diameter, made of $\frac{7}{16}$-in. plates, with flat back and hemispherical front end. A tube 3 ft. 3 in. diameter passed from the back end nearly to the front, and returned to the back end, but of 6 in. less diameter, and then passed to an iron chimney. The firegrate was beneath the hemispherical end. The working pressure was 36 lbs.

The effect of the explosion was, that the angle iron of the flat back end gave way, and it separated from the shell, and, with the

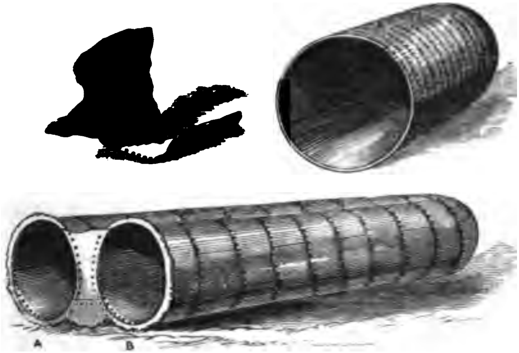


Fig. 43.

tubes attached, was blown to a good distance. The reaction drove the shell far in the opposite direction.

The cause of the explosion was the bad construction of the boiler, as the back end was quite unsupported, as there were no stays, and the bend of the tubes was not attached to the shell, and therefore the boiler was not strong enough to bear the ordinary working pressure.

An adjoining boiler, which was being cleaned inside by two men, was rolled off its seat by the force of the explosion.

No. 43. *August 7th*, 1866. 1 *killed*, 3 *injured.*

This was a railway locomotive, 13 ft. 4 in. long, 3 ft. 11 in. diameter, with 140 2-in. tubes. The firebox was 4 ft. 5 in. long, 3 ft. 6 in. broad, and 5 ft. deep. and made of copper, $\frac{1}{2}$-in. thick, and worked at 100 lbs. pressure. It was fitted with two 4-in. safety-valves and a steam gauge.

The effect of the explosion was, that the firebox gave way about the middle of the left side, 2 ft. 6 in. below the water-line, and the issuing water and steam scalded those near.

The cause of the explosion was, that the firebox was corroded to $\frac{1}{8}$ of an inch in thickness at the part which gave way.

No. 44. *August 2d*, 1866. 2 *killed*, 6 *injured.*

This was a plain cylindrical boiler, with flat ends, 23 ft. long, 5 ft. 3 in. diameter, made of $\frac{3}{8}$-in. plates, and worked at 40 lbs. pressure.

The effect of the explosion was, that both the flat ends were blown out, and the first ring of plates at the front end torn off.

The cause of the explosion was the weakness of the flat ends without stays.

No. 45. *August* 31*st*, 1866. 3 *killed*, 6 *injured.*

This was an upright boiler, 36 ft. high, 5 ft. 6 in. diameter, made of $\frac{7}{16}$-in. plates, and worked at 45 lbs. pressure.

The effect of the explosion was, that the bottom gave way, and the main bulk of the boiler was thrown straight up into the air to a great height, but descended again on its seating.

The cause of the explosion was attributed to shortness of water, but no particulars have been obtained.

No. 46. (Fig. 44.) *August* 22*d*, 1866. 3 *killed*, 5 *injured.*

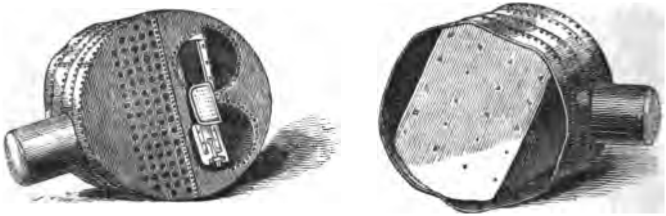


Fig. 44.

This was a marine multitubular boiler, 5 ft. 8 in. long, and 6 ft. 6 in. diameter. There were two internal tubular furnaces, which joined to an internal chamber of large size, the small tubes passed to a smokebox and chimney in the front over the fire-doors. Both ends were flat.

The effect of the explosion was, that the back was blown completely out and torn into two pieces, the lower portion remaining in the vessel, and the upper part falling in the water. The reaction of the issuing contents caused the boiler to be thrown on to the side of the quay.

The cause of the explosion was, that the flat back end was insufficiently stayed, and consequently unable to bear the ordinary pressure.

No. 47. (Fig. 45.) *August 25th*, 1866. 1 *injured.*

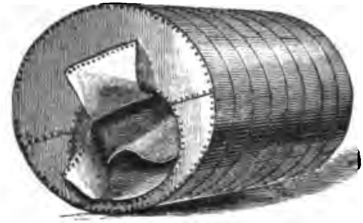


Fig. 45.

This was a Cornish boiler, 24 ft. 3 in. long, and 6 ft. diameter, with taper tube 3 ft. 5 in. diameter, for about 7 ft. 6 in. in length, and 2 ft. 6 in. diameter for the rest of the length, and worked at 33 lb. pressure.

The effect of the explosion was, that the fire-place gave way on left side, and was so much torn, that the plates were forced out of the front.

The cause of the explosion was, that the tube was so much corroded as to be too thin to bear the working pressure.

No. 48. *August 27th*, 1866. 3 *killed*, 1 *injured.*

This was a marine boiler of the usual construction, and had been tested to 60 lb.

The effect of the explosion was, that it gave way at the lower portion of the back, and the issuing steam and water scalded those near.

The cause of the explosion was a steam rent, 6 ft. 6 in. long, which had not been detected by testing.

No. 49. *August 29th*, 1866. 2 *killed*, 2 *injured.*

This was a portable agricultural boiler, and burst during a temporary stoppage from accumulation of steam, causing undue pressure; but no particulars have been obtained.

No. 50. (Fig. 46.) *September 7th*, 1866. 2 *killed*, 30 *injured*.

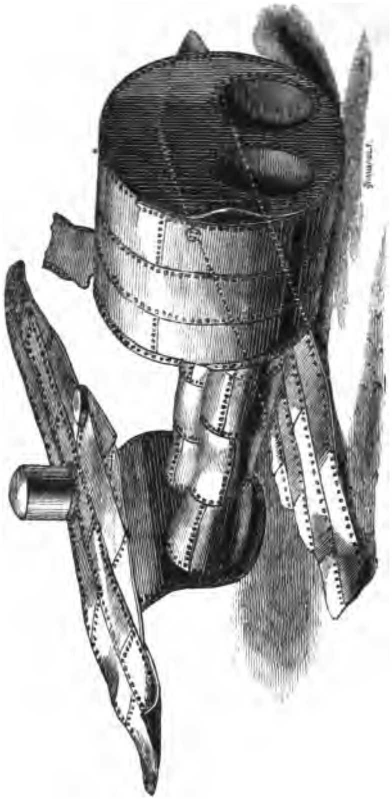


Fig. 46.

This was a Cornish boiler, 22 ft. long, 7 ft. 6 in. diameter, with 2 internal tubes, 3 ft. diameter, made of $\frac{7}{16}$ in. plates, and worked at 60 lb. pressure. There was a dome at the back part of the shell. The mountings of the boiler were efficient.

The effect of the explosion was, that some rents took place at the under side of the shell, allowing the central portion to open out and blow away. The portion containing the dome was thrown to the left, and the other to the right. The front end, with 3 rings of the shell, with the tubes and back end, were but little moved from their original position. The tubes were dented in on the top and bottom, by the fall of some large coping stones upon them, but the crowns of the furnaces were uninjured, and there was no sign of shortness of water or over-heating.

The cause of the explosion was extensive corrosion on the under side of the shell, where it rested on the brickwork, and so reduced the strength, that it was unable to bear the working pressure.

In the sketch the fragments are drawn so as to show their position when in the boiler.

No. 51. (Fig. 47.) *September 25th*, 1866. *7 killed.*

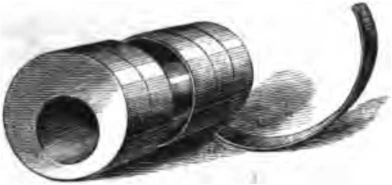


Fig. 47.

The boiler was of the Cornish type, and was 20 ft. long, 4 ft. 6 in. diameter, with a tube 2 ft. 6 in. diameter. It was double-riveted, and the crown of tube was strengthened with angle iron. The plates were $\frac{3}{8}$ in. thick. The shell was formed of six rings, each of two plates alternately jointed top and sides. The third ring from the front had stripped off, and was thrown to the right and forwards against wall. The line of rent was confined to the plates forming the ring, which was an outer one, and covered the two adjoining rings in the laps, the rent being from the edge of the inner lap to the nearest rivets. The first rent had taken place in the solid iron, about 1 in. from the rivets of a seam on one side, and from this the rent had extended along the seams on either side, and of course the whole ring soon tore off when the equilibrium was destroyed by the first rent.

The fittings of the boiler were sufficient, except that there was only one safety-valve, and that was so constructed that it could only open a very little way.

The cause was a defect in the iron at the point of first rent, and accumulated pressure during the time of standing.

No. 52. *September 25th*, 1866. *none injured.*

This was a multitubular boiler with large internal fireplace, and worked at 60 lb. pressure.

The effect of the explosion was that the whole of the furnace crown was crushed down and torn across two seams. The boiler was lifted from its seat and thrown back against a stone wall.

The cause of the explosion was shortness of water, which allowed the furnace crown to become over-heated.

No. 53. *September 23d*, 1866. 1 *injured.*

This was a plain cylindrical boiler, 7 ft. long and 2 ft. diameter, made of $\frac{3}{8}$ in. plates, and worked at 30 lb. pressure.

The effect of the explosion was that the upper part of the boiler at the first ring of plates was torn off, and the front end was blown out.

The cause of the explosion was extensive external corrosion, where the plates rested against the brick-work.

No. 54. *September 21st*, 1866. *none injured.*

This was a Cornish boiler with one tube.

The effect of the explosion was that the tube collapsed and parted, and the escape of the steam and water blew off the door-frame.

The cause of the explosion was supposed to be shortness of water, but no details have been obtained.

No. 55. *October 5th*, 1866. 1 *killed*, 7 *injured.*

This was a boiler of the ordinary agricultural type, and worked at about 45 lb. pressure. The engine had only just been set to work.

The effect of the explosion was that the crown plate to the fire-box gave way, and the issuing contents scalded those near.

The cause of the explosion was that the crown plate was so deeply corroded from long wear, that it was incapable of bearing even the ordinary working pressure.

No. 56. (Fig. 48.) *October 8th*, **1866.** **2 *killed*, 2 *injured*.**

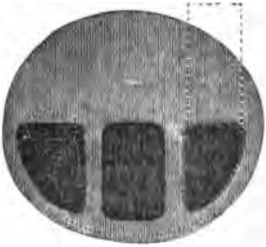


Fig. 48.

This was a marine boiler, and only intended for low pressure. While the vessel was waiting to start, with steam up, the wing furnace of the starboard boiler collapsed on the wing side, as shown by the dotted lines, and allowed the steam and water to escape into the stoke hole.

The boiler was slightly oval, and 16 ft. long. The front end was flat, 8 ft. 6 in. wide and 7 ft. 10 in. high, and the dimensions of the back hemispherical end were 2 ft. less each way. The plates were $\frac{3}{8}$ in. thick. The pressure was about 26 lb. There were two internal fireplaces, of irregular shape, uniting at the back into one flue of similar shape, which did not come to the front, but passed through the steam space, and out at the top of the boiler.

The effect of the explosion was, that the side of the furnace next the shell was rent along the edge of a longitudinal seam in a line, which was slightly nicked in the caulking. This rent extended about 5 ft. 6 in. from the front, and then at a cross seam it went along the line of rivets from the crown to the bottom of the furnace. Beyond this cross seam the furnace was collapsed, until it nearly touched the other side of the furnace, and the bulge died away towards the back end. There was also a rent in the lower part of the front of the shell, as shown in dotted line.

The cause of the explosion was the weakness of the shape of the flue, which was not stayed to the shell. It had evidently gradually been giving way some time before the explosion, and eventually collapsed at nearly the ordinary pressure. Symptoms of the same alterations of shape were noticed in the corresponding flue of the other boiler.

No. 57. (Fig. 49.) *October 9th*, 1866. *7 killed*, 1 *injured.*

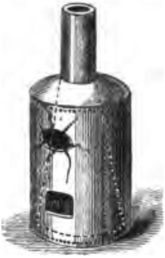


Fig. 49.

The boiler was 5 ft. 6 in. high, and 2 ft. 6 in. diameter, and had an internal conical fire-box, with two cross tubes and a chimney at the top, and was attached to a portable steam crane on board a sailing vessel.

The effect of the explosion was that the outer shell of the boiler was rent into many pieces, leaving the central conical fireplace intact. The nature of the rents showed that the plate round the manhole, which was unstrengthened by a ring, had first given way, and all the other fractures had led away from that point. This is confirmed by the fact that the manlid was thrown a good distance, with force enough to make its way through the timber walls of a cabin. The front plate divided into many pieces, and scattered right and left, while the back plate was thrown through a cabin in the opposite direction to the manhole.

The central flue showed a slight indication of over-heating, but the construction was such that the upper portion passed through the steam space, and was always exposed to the action of the fire without the protection of the contact of water. The shell of the boiler was only $\frac{1}{4}$ in. thick, and as the manhole was without a ring on its edge to strengthen the plate, and was held in by two clamps, which caused additional strain when carelessly screwed up, the manhole was by far the weakest place. The engine was standing after a short time of working, and as the safety-valve was very defective, and could be screwed down until tight, against almost any pressure, it is most probable that the pressure mounted much beyond the usual working pressure of 75 lb., when the weakest part gave way, and led to the sudden tearing up and scattering of the whole fabric.

The cause, therefore, was faulty construction of both boiler and fittings. The boiler being unable to bear that accumulated pressure which the safety-valve ought to have made impossible.

No. 58. *October* 13*th*, 1866. 1 *killed.*

This was a Cornish boiler, 14 ft. long, 6 ft. diameter, with an internal flue, 3 ft. 3 in. by 2 ft. 10 in., made of $\frac{3}{8}$ in. plates, and worked at a pressure of 27 lb. It stood on three saddles, with a bearing surface of 3 ft. by 4 in.

The effect of the explosion was that a portion of plate, 20 in. by 18 in., at the bottom of the boiler, was blown out, and the contents scalded the man who was killed.

The cause of the explosion was that the plate around this rupture was corroded to only $\frac{1}{16}$ in.

No. 59. (Fig. 50.) *November* 1*st*, 1866. 7 *killed.*

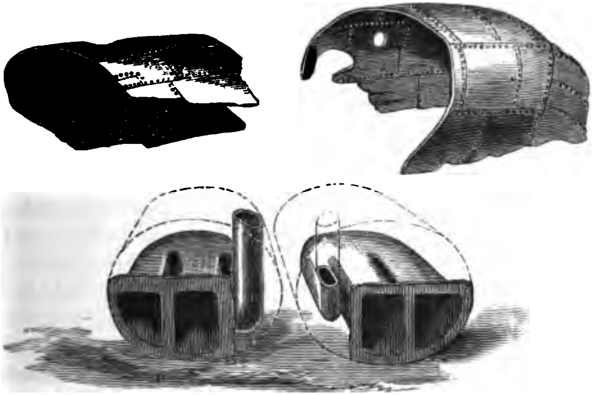


Fig. 50.

In this case two boilers exploded simultaneously, and both were on board a small steamboat. They were 16 ft. long, and 6 ft. 6 in. diameter at the flat front ends, and somewhat less at the hemispherical back ends. Each had two internal fireplaces, which united in one flue, which returned nearly to the front, and passed up through the steam space, and out at the top of shell into the funnel. The central fireplaces were not circular, and the outside fireplaces and the return flues were still more distorted, but the weakness of the shape was somewhat compensated for by stays between the tubes, and from the tubes to the shell. The mountings to the boiler were of the ordinary kind, and efficient.

The effect of the explosion was that the under side of the shell of each boiler was rent longitudinally for its whole length, allowing the sides to open out and tear away from the front end. They fell at a considerable distance. The furnaces, with parts of the front ends attached, fell into the water, but, with the exception of one of the side flues, which was a little collapsed, they were uninjured. Small pieces of the front ends were thrown to a great distance. The sides of the vessel were so completely blown out that she sank. There were no signs of shortness of water or over-heating.

The cause of the explosion was such deep corrosion on the under side of the boiler, that very little of the iron was left, so that they were unable to bear the slightly increased pressure from a temporary stoppage of the engine.

This corrosion was, no doubt, caused by the leakage of the vessel keeping the shells of the boilers constantly wet.

No. 60. (Fig. 51.) *November 3d.* *None injured.*

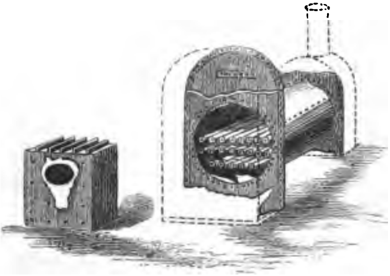


Fig. 51.

This boiler was of the locomotive or agricultural type; the barrel was 3 ft. 9 in. long, and 2 ft. 6 in. diameter. There was an internal fire-box, and the heat passed through a number of 1 in. tubes to the front smoke-box or chimney. The usual working pressure was 70 lb.

The explosion happened during a stoppage for breakfast time, and the effect was that the fire-box end was torn from the barrel, and from the position of those fragments that could be found, the boiler appeared to have turned over, as part of the fire-box was sent through the stage upon which the boiler was travelling, and the barrel with the tubes remaining in it first struck a rail, which caused it to be dented in, and then it rebounded to a point about 140 yards from its original position.

There was not enough of the fragments recovered from the river, into which they fell, to trace the cause of the explosion; but it is presumed that, although when the boiler was left only 20 lb. pressure was shown by the gauge, the fire-door being left closed, the pressure must have risen to a point much above the working pressure, and to more than the boiler could bear.

No. 61. (Fig. 52.) *October* 1*st*, 1866. *none injured.*

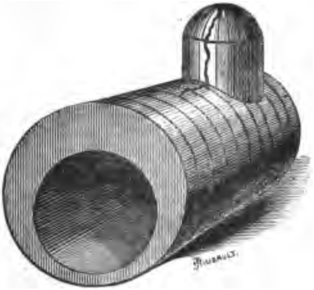


Fig. 52.

The boiler was of Cornish type, and was 22 ft. long, 6 ft. diameter, with one tube 4 ft. 6 in. diameter, and made of $\frac{3}{8}$-in. plates. The working pressure was about 12 lbs. There was an unusually large dome at the back end, 5 ft. diameter, and the whole of the shell was cut out from under it, so that the construction was peculiarly weak.

the hemispherical back ends. Each had two internal fireplaces, which united in one flue, which returned nearly to the front, and passed up through the steam space, and out at the top of shell into the funnel. The central fireplaces were not circular, and the outside fireplaces and the return flues were still more distorted, but the weakness of the shape was somewhat compensated for by stays between the tubes, and from the tubes to the shell. The mountings to the boiler were of the ordinary kind, and efficient.

The effect of the explosion was that the under side of the shell of each boiler was rent longitudinally for its whole length, allowing the sides to open out and tear away from the front end. They fell at a considerable distance. The furnaces, with parts of the front ends attached, fell into the water, but, with the exception of one of the side flues, which was a little collapsed, they were uninjured. Small pieces of the front ends were thrown to a great distance. The sides of the vessel were so completely blown out that she sank. There were no signs of shortness of water or over-heating.

The cause of the explosion was such deep corrosion on the under side of the boiler, that very little of the iron was left, so that they were unable to bear the slightly increased pressure from a temporary stoppage of the engine.

This corrosion was, no doubt, caused by the leakage of the vessel keeping the shells of the boilers constantly wet.

No. 60. (Fig. 51.) *November 3d.* *None injured.*

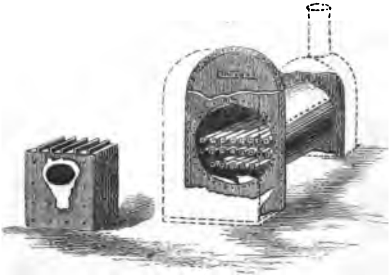


Fig. 51.

This boiler was of the locomotive or agricultural type; the barrel was 3 ft. 9 in. long, and 2 ft. 6 in. diameter. There was an internal fire-box, and the heat passed through a number of 1 in. tubes to the front smoke-box or chimney. The usual working pressure was 70 lb.

The explosion happened during a stoppage for breakfast time, and the effect was that the fire-box end was torn from the barrel, and from the position of those fragments that could be found, the boiler appeared to have turned over, as part of the fire-box was sent through the stage upon which the boiler was travelling, and the barrel with the tubes remaining in it first struck a rail, which caused it to be dented in, and then it rebounded to a point about 140 yards from its original position.

There was not enough of the fragments recovered from the river, into which they fell, to trace the cause of the explosion; but it is presumed that, although when the boiler was left only 20 lb. pressure was shown by the gauge, the fire-door being left closed, the pressure must have risen to a point much above the working pressure, and to more than the boiler could bear.

No. 61. (Fig. 52.) *October 1st*, 1866. *none injured.*

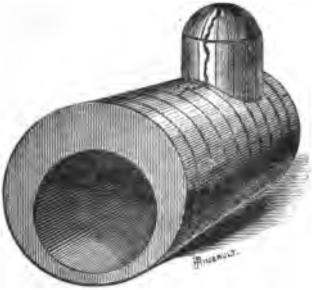


Fig. 52.

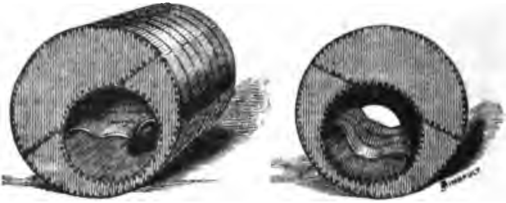
The boiler was of Cornish type, and was 22 ft. long, 6 ft. diameter, with one tube 4 ft. 6 in. diameter, and made of $\frac{3}{8}$-in. plates. The working pressure was about 12 lbs. There was an unusually large dome at the back end, 5 ft. diameter, and the whole of the shell was cut out from under it, so that the construction was peculiarly weak.

The boiler had been off for cleaning, and steam was being got up in the night, and it was said that an extra pressure was caused by the stop-valve being left closed, but it could not have been very great, or the large tube would have collapsed.

The effect of the explosion was that the dome was split in two, in the line marked in the sketch, and the shell was a little ruptured on each side of it, and so large a rent was suddenly made that the contents of the boiler passed harmlessly into the air without moving the boiler on its seat.

The cause was the extreme weakness of the shell at the juncture of the dome.

No. 62. (Fig. 53.) *November* 11*th*, 1866. 1 *killed*, 1 *injured.*



FRONT VIEW. BACK VIEW.

Fig. 53.

The boiler was of Cornish type, 16 ft. 3 in. long, and 5 ft. 8 in. diameter, with one tube 3 ft. 1 in. diameter, and was made with $\frac{1}{16}$-in. plates. The ordinary working pressure was 60 lbs.

The effect of the explosion was, that the tube collapsed from end to end. The top had fallen and the bottom had risen until they nearly met. The tube was torn away from the angle iron for the upper half of the circle at both ends. The shell of the boiler was uninjured, and the front and back flat ends were only slightly bulged outwards. The boiler had only moved about a yard backwards, and a little on one side. The discharge of the contents of the boiler from either end had knocked down the walls of the premises, and moved some machinery, and let down much roofing.

There was no indication of shortness of water, or over-heating of the plates; but the tube had collapsed from over-pressure, the man in charge having fastened three bricks to the lever of the safety-valve, under the impression that he could thus accumulate a quantity of steam during the night, to be available on commencing work on the morrow, but he was killed by the explosion.

The tube had no strengthening hoops, and was more than an inch out of the true circle at the ends, and was doubtless much more out of proper form in the centre, so that the extra pressure of the 27 lb. weight at the end of the safety-valve lever caused it to collapse.

No. 63. (Fig. 54.) *November 20th*, 1866. *none injured.*

This was not properly a boiler, as it was not exposed to the fire, but a revolving steam chamber. It was a plain cylinder with hemispherical ends, 12 ft. 6 in. long and 5 ft. diameter.

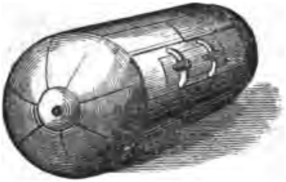


Fig. 54.

The manhole was large, to facilitate filling and emptying, and was rectangular and unstrengthened on the edges, and measured 3 ft. 6 in. in length and 1 ft. 6 in. in width. The lid fitted on the inside, and was held by clamps.

The boiler was much out of repair, and a crack shown in sketch, from one corner of the manhole to the commencement of the hemispherical end, was only temporarily prevented from leaking by a screw-patch, which did not restore the strength.

The explosion happened when, in revolving, the manlid was downwards, and the result was, that the lid was driven nearly through the floor, and the shell was rent from the opposite corners of the manhole and opened out, and the reaction of the escaping contents sent the boiler through the roof, and in descending it fell through another roof into a floor at the ground level. The rent on the side originally cracked had extended through the hemispherical end, dividing it into two halves; but on the other side the rent had followed the seam, joining the shell to the end, and had run completely round the boiler, allowing the end to be blown away.

The cause of the explosion was the extreme weakness of the construction, as the large manhole cut away nearly all the strength on one side, and the fastenings of the lid were not contrived so as to compensate at all for the loss of strength. The constant strain upon the structure, when revolving, also tended to weaken it. These two causes together were sufficient to account for the explosion, at the usual working pressure of 12 lbs., although it is possible that it might have been increased to 35 lbs., as that was the pressure in the boiler supplying the steam, although the pressure was regulated by a check-valve.

This explosion (and also No. 41 in this year) will clearly show that a mere vessel of steam not exposed to the fire, or any chance of overheating of the plates, can burst and cause very great destruction, although there could be no sudden *increase of pressure*, which is so often supposed necessary to account for the havoc caused by explosions.

No. 64. (Fig. 55) *December* 1*st*, 1866. 3 *killed*, 2 *injured*.

The boiler was of the agricultural portable class, and was 7 ft. 6 in. long and 3 ft. 8 in. diameter, made of ¼-in. plates. The fire-box was 2 ft. long and 2 ft. 10 in. broad. Two 11½-in. tubes led from it to an internal chamber at the other end of the boiler, and three 8¼-in. tubes led back again to an external smoke-box and chimney fixed over the fire-door. The boiler was mounted

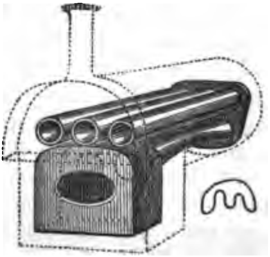


Fig. 55.

with a water-gauge, a steam-gauge, and a spring safety-valve loaded to 35 lbs. The wheels had been removed.

The effect of the explosion was, that the bottom of the right-hand side lower tube was forced upwards and rent along to within twelve inches of the fire-box.

The cause of the explosion was, that the tubes, which had been $\frac{5}{16}$-in. thick, were corroded so much from leakage, from patches in the smoke-box, that only $\frac{1}{16}$th of an inch of the metal was left, so that they were unable to bear the slight increase of pressure that had accumulated during a short stoppage.

No. 65. *December 4th*, 1866. 2 *killed*, 6 *injured.*

This boiler was of the Cornish type, 22 ft. long and 7 ft. 6 in. diameter, with two tubes 3 ft. diameter each, and they were strengthened with rings in the approved manner. The boiler altogether was strongly made, and less than three years old.

The effect of the explosion was, that the second from the back of the seven rings was ruptured at the bottom and torn off by a rent through the line of rivets on each side, and the boiler was thrown from its seat and turned completely over, so as to lie in a contrary direction to what it was before. The ring torn off was opened out flat.

The cause was extensive corrosion, which resulted from leaking of the seams beneath the brickwork, and hidden from view.

No. 66. *December 7th*, 1866. *none injured.*

This boiler was a plain cylinder with hemispherical ends, and was about 9 ft. long and 3 ft. 3 in. diameter, and was worked at something under 20 lbs. pressure. It was set in the usual way, with a fire under one end, and a flash flue.

The effect of the explosion was, that the boiler was rent all along one side, and the shell opened out, and the reaction of the issuing contents caused the shell to be thrown some yards away. One of the ends became altogether detached, and flew to a considerable distance.

The cause of the explosion appeared to be, that the plates had so much thinned by corrosion that they were scarcely $\frac{1}{16}$ in. thick, and therefore unable to bear safely the ordinary working pressure, and gave way on a very slight increase of pressure during a temporary stoppage of the engine.

No. 67. *December* 12*th*, 1866. 1 *killed*, 1 *injured*.

No further particulars have been obtained than that this boiler exploded through its being wasted by long wear and over-pressure.

No. 68. (Fig. 56.) *December* 15*th*, 1866. 5 *injured*.

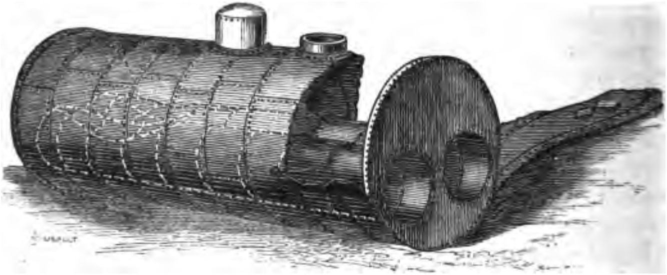


Fig. 56.

This was a Cornish boiler, 24 ft. long, 6 ft. 6 in. diameter, with two flues, 2 ft. 8 in. diameter, and made of $\frac{7}{16}$ in. plates, and worked at 50 lb. pressure. The boiler was fired in each of the tubes in the ordinary way, and also the heat from two furnaces passed from the back, one on each side of the outside shell.

The effect of the explosion was that both the internal furnaces were collapsed, until the crowns almost touched the firebars, as shown in dotted lines, but without fracture. The back of the shell, on the right side, had evidently been overheated, and had rent along the centre of a bulge, and this rent had extended along the line of rivets of the transverse seam on each side, allowing two rings of the plates of the shell to open out flat, as shown. There was a bulge on the plate, on the right side of shell, corresponding with the one which parted on the opposite side.

The cause of the explosion was overheating of the plates from shortness of water. As the glass gauge showed plenty of water just before explosion, it is presumed that the bottom stop-cock was stopped up.

No. 69. *December* 24*th*, 1866. 1 *injured*.

No particulars have been obtained.

No. 70. *November 26th*, 1866. *None injured.*

This boiler was 28 ft. long, 7 ft. diameter, made of $\frac{7}{16}$ in. plates, and worked at 50 lb. pressure. There were two internal fire-places united into one tube beyond.

The effect of the explosion was that the sides of the oval chamber forming the junction of furnaces and tube crushed inwards.

The cause of the explosion was, that this chamber was of such weak shape as to be unable to resist the ordinary working pressure."

21. *Explosions from Overheating Boilers.*—" We have a communication from an able correspondent relative to the causes of steam boiler explosions, in which he reckons the following as a prolific cause : 'The sudden formation of steam caused by a change in the position of the boiler,—the sudden starting or stopping of a locomotive, the rolling of a steamer, or any sudden shock given the boiler. This formation of steam is caused by the water in the boiler being thrown suddenly on the sides of the boiler not before covered by water. An immense volume of super-heated steam is thus formed, as it were, in an instant, exerting a greater pressure than that which the boiler is calculated to withstand.'

We do not entirely agree with our correspondent in his views. If they were correct, explosions of the boilers of sea-going steamers should be much more frequent than they are. An article in the London *Mechanics' Magazine* puts the subject in a more reasonable light, we think. This article says :—

'A great number of boiler explosions are attributed to overheating : in fact, some theorists go so far as to assume this as the general cause of such catastrophes. Now this theory, taken in a broad sense, is a false one, although it is possible that a boiler may be exploded by the formation of a great quantity of steam from water thrown upon red-hot plates. But a consideration of some of the phenomena of heat places this possibility at the farthest limit, and the occurrence of an explosion from such a cause only just within its bounds. We quench the heat of a railway tire in a cistern, and why may we not as safely fill a red-hot boiler with cold water ? It is surprising to see how small a quantity of steam is disengaged when a large body of wrought iron is plunged into twice or thrice its weight of cold wa

Now if we reverse the operation, and dispose the same weight of metal in the form of a boiler, heat it to the same degree, and throw the same quantity of cold water into it, is it not reasonable to expect that exactly the same amount of steam will be produced? If so, where would be the harm done to the boiler beyond the damage inflicted upon the iron by burning?

If we look into the matter a little more closely, we shall find that the metallic plates of a steam boiler are not capable of containing sufficient heat to change a very large quantity of water into steam. The total quantity of heat which would raise the temperature of 1 cwt. of iron through one degree would, according to the best authorities, impart the same additional temperature to 12½ lb. only of water. And this makes it clear that overheating is not the sole cause of an explosion, although it may lead to a rupture by weakening the plates.'

The writer fortifies his position by the following account of an experiment:—

'An empty boiler 25 ft. long and 6 ft. diameter, and with the safety-valve loaded to 60 lb. per square inch, was made red hot. While in this condition the feed was suddenly let on and the boiler filled up. The experimenters expected a mighty explosion, for which they were fully prepared, but no such event occurred, the result being simply a sudden contraction of the overheated iron, which allowed the free escape of the water at every seam and rivet as high as the fire-mark extended. Although we were not witnesses of the occurrence, yet arguing upon the hypothesis regarding the action of heat already referred to, we cannot hesitate to accept the fact; the more so in that we have heard of other experiments of a similar character having been made, and which were attended with similar results.'

Charles Wye Williams maintained that steam in a boiler under pressure is as much in the water itself as in the steam space. He contended that in the case of an explosion the globules of steam contained in the water and confined by pressure in a medium over eight hundred times denser than the steam alone, fly into the steam space when the pressure is removed, and expand in volume in proportion to the density of the two mediums, or over eight hundred times. The *Mechanics' Magazine*, however, adopts the theory of Mr. Zerah Colburn, and says:—

'In all boiler explosions, the pressure of steam is instantaneously liberated from the surface of the hot water present. Assuming the boiler to be at work at a pressure of 45 lb., the water will be at a temperature of about 290 deg. Now fresh water cannot for an instant be maintained at a temperature much greater than 212 deg., under the ordinary atmospheric pressure. If, therefore, the pressure upon it be suddenly liberated when heated to (say) 290 deg., a most violent disengagement of steam, and projection of water along with it, must inevitably take place. The shells of boilers are constantly liable to rupture from original unsoundness of the iron, bad riveting, corrosion by bad water, or furrowing. This being the case, what are we to expect when the opening of a weak point suddenly liberates the steam pressure from 30, 40, or even 60 tuns of heated water, which are waiting below to burst partly into steam? To render the matter perfectly intelligible, we will state the distinct and consecutive operations into which, according to Mr. Colburn, a boiler explosion, although practically instantaneous, may be resolved. They are, first, the rupture, under hardly if any more than the ordinary working pressure, of a defective portion of the shell of the boiler—a portion not much, if at all, below the water-line. Second, the escape of free steam from the steam chamber, and the consequent removal of a considerable part of the pressure upon the water, before its contained heat can overcome its inertia and permit the disengagement of additional steam. Third, the projection of steam, combined, as it necessarily must be, with the water, with great velocity, and through a greater or less space, upon the upper sides of the shell of the boiler, which is thus forced completely open, and perhaps broken. Fourth, the subsequent disengagement of a large quantity of steam from the heated water, now no longer confined within the boiler, and the consequent projection of the already separated parts of the boiler to a greater or less distance. This unique theory harmonises so well with the circumstances of steam boiler explosions, that we can admire and accept it. It is so consistent with all the phenomena attending these explosions that it leaves no room for doubt or questioning as to its soundness. It receives support from the well-known fact that boiler explosions frequently take place at the starting of the engine, when there is a sudden withdrawal of pressure in the boiler. The most conclusive evidence of the soundness of the theory, however, would be suddenly to condense steam in the steam chamber of a boiler at work, and to watch the results. If a boiler were half-filled with water, and the steam got up to 30 lbs. or 40 lbs., and if a quantity of water were suddenly thrown into the steam space, the steam would be suddenly condensed, and an explosion of the boiler would doubtless follow. Such an experiment would of course be attended by considerable danger, and the object gained would probably after all be very inadequate to the risk involved. It seems to us, however, that the question has just been practically solved, and the only evidence wanting actually supplied, although under most distressing circumstances. We allude to the recent loss of the *Ceres*, in the reports of which catastrophe it is stated that the sea rushing suddenly in upon the boilers caused them to burst with fearful results. If this be correct—and all accounts agree upon the point—here is a singular though melancholy confirmation of Mr. Colburn's theory. The cold water suddenly cooled the boiler plates, condensed the steam in the steam space, relieved the pressure on the lower part, and forthwith the steam and water from below burst forth with resistless energy upon their errand of destruction."—*Scientific American.*

22. *Overheated Steam Boilers.*—As closely bearing upon one of the points referred to in last par., and in answer to a question which has been put,—"Can a red-hot boiler be exploded?"—we give the following report, by Mr. Fletcher, of the Manchester Boiler Association for the Prevention of Boiler Explosions. The experiments here detailed were carried out with a view to decide the question, as to whether the explosion of household boilers in frosts were caused by the sudden influx of cold water on hot metal by the thawing of the ice in the inlet pipe.

"Three different boilers were experimented on, all of them being of the ordinary household circulating class.

The first of these boilers was made of copper, weighed 62 lbs., and measured 14½ in. in height, 11¾ in. in width, by 13¾ in. in depth at the bottom, and about 8 in. at the top, which gave an internal capacity of one cubic foot as nearly as may be. This was placed, when perfectly empty, on the top of a briskly burning fire, as well as surrounded with it, and allowed to remain so for a considerable time, till the bottom became thoroughly red-hot, and lumps of lead freely melted though but loosely laid on the top, which was the coldest part of the boiler, being out of the reach of the flames. When the boiler was in this condition, water was suddenly let into it through a pipe about half an inch in bore, connected to the Water Company's main. No explosion, however, took place, the boiler was not stirred from its seat, neither did it tremble or evince the slightest signs of internal commotion; all that took place was a rush of steam through an outlet ⅞ths of an inch in diameter, left on the top of the boiler. It was necessary to have this opening, or the water would not have found its way into the boiler at all, as was proved by actual experiment with it closed, when the first puff of steam generated forbade the entry of more water, and drove it back through the feed-pipe. The opening, however, would not have had the slightest effect in preventing the bursting of the boiler, if the views entertained with regard to the explosive effect of dashing cold water on red-hot plates were correct, the action of which is supposed to be as irresistible and instantaneous as that of gunpowder.

The result of this experiment was so unmistakable that it appeared of itself to be conclusive, but still it was thought more satisfactory to repeat it with another boiler, of slightly different dimensions, by way of corroboration.

The second boiler, which, like the first, was of copper, weighed 44 lbs., and measured 11¾ in. in height, 11⅛ in. in width, by 10½ in. in depth at the bottom, and 8½ in. at the top, having a flue tube running through it 6 in. in diameter, so that it had an internal capacity of about ⅝ths of a cubic foot. This boiler was surrounded, just as the previous one had been, by a brisk fire, which operated not only on the bottom and sides, but also on the internal flue tube, and it was allowed to remain perfectly empty, as in the previous experiment, until lead, loosely laid on the top, freely melted, and nearly half of the boiler became red-hot, when water was suddenly turned into it through a pipe of 1 in. bore, connected to the boiler at one end and to a tank; affording a head of from 6 ft. to 8 ft. in height, at the other. This plan of feeding was adopted in preference to that in the first experiment, thinking that the increased size of the pipe would give a more sudden injection of water, and thus prove more favourable to an instantaneous generation of steam. The result, however, was precisely the same as in the previous experiment; no explosion whatever occurred, the boiler remained perfectly still, and the only effect of the injection of the water was the escape of a jet of steam through an orifice 1 in. in diameter, which had been left open on the top of the boiler.

This experiment, therefore, completely corroborated the previous one; but inasmuch as both of the boilers referred to above were made of copper, whereas many in use are made of cast-iron, it was thought well to repeat the experiment with a cast-iron boiler, which it was expected would prove more favourable to explosion, not only on account of the brittleness of its material, but also from its greater weight of metal, which would afford increased capacity for heat, and thus for rapidly generating steam.

The third boiler, which, as just stated, was of cast-iron, weighed 85 lbs., and measured 15¼ in. in length, 10 in. in height, by 11½ in. in depth at the bottom, and 8¼ in. at the top, having an internal capacity of less than a cubic foot, while the bottom was arched, which increased the heating surface. This boiler, like the previous ones, was heated till the greater part of it became red-hot, and lead melted on the top; indeed, it was in such a glowing heat that it appeared, on looking into it through a small orifice, as if the bottom had been burnt out, and the eye was looking directly into the fire itself. Water was then laid on, as in the previous experiments, by means of a pipe 1 in. in diameter, connecting the boiler to a tank giving a head of from 6 ft. to 8 ft., but there was no orifice left open on the top of the boiler as before, a safety-valve, loaded to a pressure of about 35 lbs. on the square inch, being substituted. On opening the tap in the connecting pipe, and letting the water on, no result whatever was apparent. The safety-valve did not blow, and the boiler neither cracked nor trembled, but the feed-pipe was found to get hot up to the tap, some 15 feet from the boiler, as if the steam was beating back and forbidding further entry of the water. After allowing the boiler to rest in this position for some time, with the fire briskly burning around it, the safety-valve was lifted, when a very moderate escape of steam took place, and continued as long as the valve was kept open, but ceased as soon as it was allowed to fall.

Finding that no result could be produced with the safety-valve attached to the boiler, it was removed, and an orifice of 1¼ in. in diameter left open instead. On turning the water on again a jet of steam escaped from the orifice as before, and shortly after the boiler cracked on one side from the top to the bottom with a sharp report. This was due simply to the contraction of the metal, and the rupture did not spread, neither did the boiler stir from its seat. The water was kept on till the boiler was nearly filled, but no result followed different to those already described.

To render the experiments as conclusive as possible, it was thought well to repeat the last one for corroboration, and therefore the boiler was removed from the fire, emptied, and replaced, the connections being completed just as before with the exception that the safety-valve was omitted, and the orifice on the top reduced to a diameter of ⅜ths of an inch. On turning on the water again, the only result was a jet of steam as before, which issued from the orifice on the top of the boiler in a constant stream as long as the feed tap was kept open, and intermittently when it was opened and closed alternately.

It should be added that the capacity of these boilers was such that a pressure of about 150 lbs. on the square inch would have been generated within them by the evaporation of a quarter of a pint of water in the two larger ones, and an eighth of a pint in the smaller one, and though they were heated all over, as already described, yet it is clear that that pressure could never have been attained, or even approached, as the light, flat-sided copper boilers did not bulge in the least, while the rush of steam from the outlet never appeared more than could be taken off by an ordinary safety-valve.

It will be seen from the results of the foregoing experiments, that all the attempts to explode the boilers totally failed. Every endeavour, however, was made to succeed, and everything that glowing red-hot plates and cold water could do, under the circumstances described, was done; while it is thought that the test adopted was much more severe than any which could occur in actual work, either to a household boiler on the occurrence of frost, or to one employed for engine-power on the furnaces being overheated, and the feed suddenly readmitted to the red-hot plates. In the case of the household boiler, the fire rarely operates further than upon the bottom and one or two of the sides, whereas the experimental ones were completely surrounded by fire, so that the amount of heated surface was greater in the experiment than it could be in practice; while the injection of the water through the supply-pipe of an inch bore, simply by opening a tap, was, it is thought, at least as sudden as it possibly could be by the thawing of a column of ice; added to which it was shown by experiment that the water would not flow into the boiler without a free outlet as well as a free inlet, so that unless both of the circulating pipes were open at the same time but little water would get into the boiler. In the case of the steam boiler for engine purposes, its capacity would be very much larger in comparison with the amount of heated surface exposed on the furnace-crowns being laid bare than in the experimental ones, so that the force of the steam would be proportionately reduced, and so much so in practice as to be completely swallowed up.

The experiments were witnessed by others as well as myself, the desire of all being to make them as satisfactory and conclusive as possible; and, though we failed in exploding the boilers, I trust something may have been done towards exploding the theory they were instituted to test—a theory which has done so much to perpetuate fatal steam boiler explosions by arresting full investigation, and throwing dust in the eyes of coroners and jurors, while inquiring into the cause of these sad catastrophes.

These experiments may, it is thought, be accepted as conclusive, that the idea of explosions arising from the instantaneous generation of a large amount of steam through the injection of water on to hot plates is a fallacy; and that the bursting of circulating boilers during frost is due simply to accumulated steam pressure within them from the choking of the outlet pipes with ice, while that pressure may be relieved and explosion prevented by a good safety-valve, as previously recommended."

The following, from a paper on "*Overheated Steam Boilers*" in the "Mechanics' Magazine" of May 24th, 1867, are comments upon the above detailed experiments, which, says the writer, "prove most conclusively the impossibility of exploding a red-hot boiler by the sudden injection of a stream of cold water. Every endeavour, however, was made to succeed, and everything that glowing red-hot plates and cold water could do under the circumstances was done. Indeed, the test adopted appears to have been much more severe than could occur in ordinary work, either to a household boiler on the occurrence of frost, or to a boiler employed for engine power on the furnaces being overheated, and the feed suddenly readmitted to the red-hot plates. In the case of the ordinary household boiler, the fire rarely operates over such an extensive surface as in the experimental one. The amount of heated surface was, therefore, far greater in the experiment than it could be in practice. In the case of the steam boiler for engine purposes, its capacity would be very much larger in comparison with the amount of heated surface exposed on the furnace crowns being laid bare, than in the experimental ones, so that the force of the steam would be proportionally reduced, and so much so in practice as to be completely swallowed up. It may, however, be urged by some that, inasmuch as steam power boilers are ordinarily constructed of wrought-iron plates, and have seams of rivets running along and around them, they were not fairly represented in Mr. Fletcher's experiments. To such as raise this objection, we would observe that an ordinary wrought-iron boiler was thus treated some ten years since. The boiler was 25 ft. long and 6 ft. in diameter, the safety-valve was loaded to 60 lb. per square inch, and the empty boiler was then made red hot, the feed suddenly let in, and the boiler filled up. The only result was a sudden contraction of the over-heated iron, which caused the water to pour out in streams at every seam and rivet as far up as the fire-mark extended. Although in each case the experimenters failed to explode the boilers, it is to be hoped they have done something towards exploding the theory the experiments were instituted to test. The results may be accepted as conclusive that the idea of the explosions arising from the instantaneous generation of a large amount of steam through the injection of water on to hot plates is a fallacy. The metallic plates of a steam boiler are not capable of containing sufficient heat to change a very large quantity of water into steam. The total quantity of heat which would raise the temperature of 1 cwt. of iron through 1 deg., would impart the same additional temperature to 12½ lb. only of water. The quantity of heat which would raise the temperature of 1 cwt. of copper through 1 deg., would raise that of ·10 2-3 lb. only of water to the same extent. It is clear then, both theoretically and practically, that overheating is not the cause of violent boiler explosions. And we, therefore, hope that such nonsense will cease to be imported into judicial investigations into the causes of accidents arising from steam boiler explosions."

23. From the "Scientific American" we take the three following articles:—

(*a*) *Boiler Explosions not always Mysterious.*—"At intervals, recurring with terrible frequency, the readers of our public journals are startled and shocked—if familiarity has not indeed bred callousness—by accounts of steam boiler explosions, attended always with loss of property, and often with loss of life or limb. To no other subject is the old adage, 'in too much discussion the truth is lost,' more applicable than to that of boiler explosions. The cause of these catastrophes has been so muddled by wordy dissertations, mysterious theories, and senseless conjectures, that few think of looking directly at the facts of each individual case and deciding each on its own evidence. Mysterious agencies, under the names of 'contraction,' 'expansion,' 'electricity,' 'development of explosive gases,' and others, figure conspicuously in the reports of committees of inquiry. The causes which are most obvious, or could be most easily ascertained, are overlooked, and the investigators go prowling about among unknown or not understood forces, to find that which frequently is before their eyes. Braces originally too weak, corroded, or improperly located; plates running longitudinally instead of circumferentially; defective riveting; plates weakened by large holes not filled with the rivets; deficiency in the thickness of plate; poor iron, and carelessness in calking, are overlooked, to say nothing of corrosion from impure water, hard firing, or neglected water feed, and incompetent attendants. Sometimes, in riveting, the holes in the plates diverge half their diameter, and they are reamed to a circular form, or enough to admit the ordinary rivet, which cannot fill the space, and depends for its security wholly on the juxta-position of the heads with the surface of the plates. Heat expands the iron, loosening the rivets, the water works through, and, if containing salts, oxidises the iron, opening the way for a rupture. The careless use of the calking chisel sometimes cuts into the plate $\frac{1}{3}$ or $\frac{1}{4}$ of its thickness, so that when an explosion occurs the line of the fracture follows the channel thus made as the breaking of glass follows the diamond scratch.

In connection with these remarks we cannot help referring to an accident to a fine steamer only a few months ago, by which a number of persons lost their lives. An investigation was had before the coroner's jury, which resulted in a perfect mystification. Yet the cause or causes should have been apparent in several facts which were ascertained. First, the part of the boiler that gave way was so deficient in substance, that, at the maximum working pressure, the iron was strained to nearly its rupturing limit; the factor of safety, instead of being 5 or 6, being hardly above 0. Second, the sheets, instead of being placed circumferentially, so that the joints would not be so long in the direction of the length of the cylinder, and so that each would support the adjacent ones, were placed with the long diameter running lengthwise. Third, the calking iron had injured the iron along the seams nearly 20 per cent., and the braces were placed in an improper manner. It can scarcely be contended that this was an exceptional case. It is to be feared that many of our boilers would not stand a thorough scrutiny on these points. Mr. Edward B. Martin, an eminent engineer of Stourbridge, England, recently read before the Institution of Mechanical Engineers a paper which exhibits the following facts:—During the present century there have been 1,045 boiler explosions in England, causing the death of 4,076 persons and injuries to 2,903. Of the 1,045 explosions, 397 were 'uncertain' as to cause; 137 were from over-pressure, from the wedging or over-weighting of safety-valves, or from other facts of carelessness; 119 from collapse of internal flues; 114 from shortness of water, or from incrustations, and 9 from extraneous causes not immediately connected with the boiler. From these facts Mr. Martin expressed himself as opposed to all ideas of internal detonation, spontaneous generation of explosive gases, or other mysteries. If this is approximately a correct exhibit of the causes of boiler explosions in England, need we look for some mysterious and unknown agency to account for similar occurrences here? It is well known that English mechanics and engineers are held to strict accountability by the laws, much more so than in this country. It may be claimed that the tenacity of American boiler plate is superior, and such extreme caution as is enforced in England is unnecessary here; but in this matter as in others it is 'better to be foolishly careful than foolishly careless.' We believe that a rigid examination of boilers and a thorough oversight and testing during the process of manufacture, as well as after completion, enforced by legislative penalties, would prevent some, at least, of the destructive explosions which we are too often called upon to deplore."

(*b*) *Corrosion of Steam Boilers.*—"The process of corrosion is very similar to that of the combustion of fuel, the only difference being that in corrosion the metal unites with the corrosive agent slowly, while in combustion the fuel unites with the supporter of combustion rapidly.

The external corrosion of a boiler is due to simple oxidation caused by atmospheric exposure principally. In the boilers of sea-going vessels it is also caused by the contact of the bottom of the boiler with bilge water, and by the exposure of the top to leakage from deck. The best means of preventing this is to cover the top with felt and sheet lead soldered at the joints, and to keep the bottom thoroughly painted.

The internal corrosion is due to simple oxidation and to the galvanic action taking place whenever two different metals or a metal under different conditions are either wholly or partially immersed in a fluid in which either of them would be oxidized; that is, united with the oxygen of the corrosive agent; and which has the effect of confining the corrosion principally and sometimes wholly to one of the two metals in contact. The sheets are eaten away around the rivets before the rivet is injured, on account of the iron in the rivet being in a different condition from that in the sheet, owing to its being more dense from being hammered until cold, and consequently producing a galvanic action by which the sheet is corroded. Tube sheets are apt to leak, when the sheet and tubes are composed of different metals, from the effect of the galvanic action produced by them.

The hot brine or sea water contained in marine boilers is a most powerful corrosive agent of wrought iron. Hence the stays are corroded and the pins or bolts which hold the stays are eaten and loosened. A very thin film of scale is the best protection against this kind of corrosion. The corrosion of the steam drum is caused by the high temperature of the uptake, about 600° Fah.

for natural draft, thereby super-heating the steam and oxydizing the iron in a similar manner to the making of hydrogen gas by sending steam over red-hot iron. Boilers not in use are liable to corrosion on the fire side of the heating surface as well as on the water and steam side. To prevent this the smoke stack should be covered over to keep out rain and moisture, the man-hole plates taken off so as to allow a free circulation of air inside, and a light fire of shavings should be built occasionally to dispel all moisture."

(c) *Explosion of Boilers.—A New and Simple Preventive.*—"In an experience of about eighteen years, and with pretty close observation of causes and effects, I think I have demonstrated that boiler explosions result from two common, plain and simple causes, and if there is any mystery about the matter with me, it is that explosions are not many times more numerous. The first of these causes is simply the severe tests boilers are subjected to daily and hourly in ordinary usage, not intentionally, but from want of knowledge of causes and effects. To explain: it is and always has been a common practice in feeding or supplying boilers to discharge the feed pipe into the under side of the after end of the boiler, or into a receiving drum, which discharges in the same place. This feed water, though always intended to be comparatively hot, is not always so: on the contrary, it is sometimes tolerably cold. Now all boilers under a pressure of steam are fully expanded, and as a matter of course, if supply or feed water is discharged comparatively cold, as it is usually, on the bottom shell of the boiler, it must produce a sudden contraction of the part so cooled, and if the iron is not very soft and tough the sheet will tear apart, sometimes in the middle, sometimes in the lap between rivets. This I have known very many times to the extent of ten to fifteen inches. This you will see is a good start for an explosion, provided, of course, the boiler is carrying a fair working pressure of steam, and as is almost always the case, the iron in two-thirds of the circumference of the shell is no better than that already broken.

The second great cause is the carbonized, hardened, brittle condition of that portion of the shells of boilers exposed to a very intense heat, and this heat, as is usually the case, generated with coal more or less impregnated with sulphur. Under these circumstances boilers in use from six months to two years always become more or less carbonized or hardened and brittle, and will not stand the test of sudden contraction by cooling parts, as above described. It sometimes happens that iron in new boilers, or parts of them, is more or less hard and brittle, and of course in a measure liable to the same misfortune under the same circumstances as before described. Now when we add to the other two causes, and in combination with them, the carrying by engineers of all the pressure allowed by law, and sometimes a good deal more, it is certainly not strange that explosions so frequently occur, for we have here all the causes in combination to produce that effect, and the wonder, as I have before stated, is that explosions are not many times more frequent. I am satisfied, however, that very many explosions have occurred with only an ordinary working pressure, and mainly from the first two causes, namely, sudden contraction of parts of the shell, and the hard and brittle condition of the iron.

I promised a remedy, and here it is. Some year and a half since I was repairing a boiler that had been blown up by the explosion of another alongside of it. We found the iron so hard and brittle that we could not punch or bend without breaking it. Finding it impossible to do anything with it in that state, and knowing I could not make it any worse, I suggested to Mr. Webb, my foreman, the idea of annealing it, which he did, and with the most signal success: nothing less than completely restoring the iron to a uniform soft and tough state, and I think better than it ever was before. Since that time I have annealed all the boilers I have used, with the same success. This annealing process is simple, cheap and safe, loosening not one seam or rivet, and consists merely of draining the boiler dry when in the furnace, then firing up with dry wood until the boilers are barely red hot, then cooling as gradually as possible, and the thing is accomplished. In conclusion, I will say that all new boilers, no matter how good the iron, should be annealed. It will in any case give to all the plates a uniform toughness and temper. I will say further, that with careful superheating of feed-water before it can touch the shell of the boiler inside, and with the annealing process, which should be repeated every six months, boiler explosions will be things of the past. This sudcontraction of parts of boilers is caused sometimes by cold ter, or cold blasts of air coming in contact with the outside ll, with more or less the same effect. Of course care should taken to keep water well over the flues, to prevent them m heating and collapsing. And now, hoping you will speedily ve this nut to your numerous readers—among whom are the *vants* of the age—to crack, as well as for those using boilers to ofit more or less by, I am very respectfully yours, C. S. EBAUGH."

DIVISION SECOND.

FUEL AND FURNACES.

SECTION FIRST.—FUEL.

24. *Artificial Fuel at the Paris Exhibition,* 1867.—The Paris Exhibition of 1867 was the means of making for the first time publicly known the results of the more recent attempts to make artificial fuel from the vast heaps of coal refuse which is met with at all our coal-pit mouths. The presence of these vast masses—nuisances, in fact—of coal refuse at our coal-pits, has led, for a long time, practical men to try some means of utilizing them ; for that this refuse, if properly used, was a highly valuable material as a fuel, admitted of no doubt. For long the object aimed at was met in a variety of ways, all more or less inefficient. The coal was either pounded into smaller pieces than it naturally possessed, so as to make it uniform in character, or it was ground into dust, and finally made into blocks by the aid of great pressure and some cementing material. The difficulty in many cases was, however, to have the matter of the blocks so composed, that when put into the furnace where they were to be consumed, they should not crumble at once down, but retain their form till gradually consumed, just as other blocks of ordinary coal would be consumed. In some cases, where the refuse of highly bituminous coal was used, it was found that pressure caused the particles to cohere so firmly together that this retention of form so necessary

for practical purposes was secured. The reader will here note, that where the blocks at once crumbled away with the heat to which they would be subjected in the furnace, they could not be manipulated and used in the ordinary way and in ordinary furnaces with comparatively wide-spaced fire-bars. But even in these cases the coherence of the particles, although sufficient to keep the blocks in shape in the furnace, was not so to keep them during the rough work of transportation from place to place. A cementing material was therefore looked for, and at one time thought to be obtained in the use of clay; but this was incombustible, and caused a large percentage of ashes. Coal tar was then used, and with much greater success; but still, from the low melting point of the tar, the blocks, when exposed to a high temperature, did not retain their form in the furnace for so long a period as was desired. At last a substance was discovered to be the very kind of cementing material required, and which left behind no ashes in burning, and could stand any degree of temperature, and thus retain the form of the blocks till properly consumed. And, singular to say, it was a waste substance which, like any waste substance, was, from its quantity, and otherwise useless nature, as great a nuisance at the works which originated it as were the heaps of coal refuse at the pits, the mouths of which they encumbered,—this substance being one of the waste organic products of the starch manufacture. What a fine realization of the most remarkable feature of modern times—the utilization of waste substances! We shall learn by degrees, surely, that nothing is waste. We do not know to whom the discovery of the application of this waste substance is due, but it appears that the manufacture of artificial fuel is at present carried on exclusively on the Continent, in France, Belgium, and Austria. Some idea of the importance to which this branch of industry has already attained may be gathered from the fact that one establishment alone produced last year no fewer than 175,000 tons of fuel made in this new way. It is almost impossible to over-estimate the value of the trade which will sooner or later rise in this country when once the attention of our leading men is attracted to the matter, as we believe it now is being attracted. The fuel can be made in blocks of any shape or form; the machine adopted by M. Evrard, of the Coal Company of Chazotte, near St. Etienne, in France, passes the fuel through pipes, so that the blocks are cylinders. They are, however, more generally formed like bricks. The fuel is then easily packed away, it is clear when kindled, and, above all, it is equal in all and superior in some cases to the best solid natural coal. It is already largely used both on railways and steamers, as well as on land engines, and is found so good that its use is rapidly extending. It has been remarked that if the samples of this fuel, and the models, &c., of the machinery used in making it, which are to be met with in the Exhibition, led to a still more extended application of the principle adopted in utilizing the material of which it is made, the Exhibition will, in this alone, far more than transcend the expectations of those who looked for a large advance of practical science from it; for, as before said, it is difficult to over-estimate the enormous wealth which has yet to be realized from our now neglected coal refuse heaps. For the first time the world has seen the problem solved which has as long attracted the attention, as it has baffled the wisdom, of those who have been interested in the utilization of this vast amount of waste material. Many very interesting models, &c., were exhibited in connection with this industry. In some kinds of coal there is much matter, such as pyrites, which requires to be got rid of before the refuse can be used for artificial fuel,—this is done by washing it with water in appropriate machines. The artificial fuel produced on the principle described possesses many advantages; as above stated, it is easily packed away in small space, it is clean, it is in regular form, and gives but little ashes,—2 to 5 per cent. only. Its heating effect is high; thus, the fuel of Chazotte, when used in the boats of the Messageries Imperiales, was found to be superior to the best Cardiff coal to the extent of 10 per cent., weight for weight. In locomotive practice in the Northern Railway of Austria, a pound of the fuel was found to evaporate from seven and a tenth to seven and a fifth pounds of water,—an effect equal to ordinary coal; while the cost is considerably below.

Those who wish to know the nature and the number of exhibits in connection with *coal* at this Great Exhibition, will find pretty full details in two articles in the "Engineer," under dates July 5th and July 19th, 1867. From these two papers we take the following brief paragraph, as indicative of the position which the various countries exhibiting took in this department. After referring to the exhibits—very few in number—of the British Department, the writer says :—" We believe we have now mentioned most of the English exhibitions of coal. Of apparatus, machinery, and methods of extraction there is an entire dearth. With the coal exhibits themselves, as we have said before, we have no fault to find ; but we are rather inclined to think they might just as well not have been there at all, as scarcely any pains have been taken to set forth their qualities, and not the slightest attempt has been made by our commission, or anybody else, to illustrate the enormous proportions of this great and truly national industry and source of wealth. There may always be the same answer made to our fault-finding *cui bono*, but we reply that England having appeared at all—and having voted a very large sum to pay for appearing, ought to have been made to cut a better figure in the regions of Old King Coal, as the *Moniteur* says we call it."

In the American department the writer stated that there was " a large and varied collection of specimens, and although their executive has also failed to illustrate the collective extent and importance of their coal-workings, they have to a certain extent made up for the deficiency by a very concise notice in their catalogue. . . . The Americans have sent us no models of coal machinery, but it was not to be expected that they would, as of course the coal trade is still in its infancy there—enormous though it is already—anything like an exhibition of actual machinery would, we need hardly say, have been impossible, and also useless, as the time has not yet arrived for America to spare us anything large in the mechanical line.

When we turn to France we find that in coal-mining, as in everything else, her utmost prowess has been put forth to show the world what she can do, and no one can deny that she has succeeded well. Her admirable school of mines, which has sent forth an army of trained engineers already to contend with the peculiar difficulties under which the trade labours in France, has furnished quite a library of maps and plans, arranged on a large stand in the machinery gallery, besides endless sections which cover the walls. To attempt to describe these in general would be impossible ; we can only say of them that, admirable in detail, they show well the extent to which high scientific education has been brought to bear, both in the discovery of the small and scattered mineral basins which are dispersed over France, and in the practical development of them when found, notwithstanding the disjointed nature of the strata in general."

25. *Effect of Exposure on Coal.*—By Professor Rockwell.—"The deterioration which coal suffers from exposure to the weather is far greater than the majority of people suppose, especially if their attention has not been called to the subject. The importance of keeping it as dry as possible from the time it leaves the mine till it reaches the stove or furnace seems to have escaped notice. The consumer orders his coal of the dealer without asking the question, if it is freshly mined and has been kept well sheltered under a tight roof, or whether it has lain for months in a great heap, exposed to the showers and sun of summer, or to the storms and alternate freezing and thawing of winter; and yet these are points well deserving attention, as recent investigations have most clearly shown. Different kinds of coal are differently affected by this exposure; some to a far greater degree than others, but all more or less injured. Anthracite suffers least, as might be inferred from its hard compact structure and glassy surface, which render it more impermeable to moisture. The igneous action which has converted it from bituminous to anthracite has driven off the greater part of the volatile ingredients, and left the residue less liable to decomposition. The cannel coals rank next in power of resisting the action of the weather. The bituminous coals are the most affected, and these again in different degrees according to their hardness and compactness, and the amount of bituminous matter (so-called) which they contain. The effect of exposure on this last class of coals has recently been most carefully and thoroughly investigated by Herr Grundmann, at Tarnowitz, in Germany, and the results have been recently published. Some three years or more ago he had made a series of experiments of a similar character, and found that the coal exposed to the weather in heaps, lost during a period of nine months 50 per cent. of its value as fuel. This result, so astounding, raised doubts in the minds of others of the accuracy of his observations and conclusions. He has accordingly now instituted a new set of experiments to correct or verify his former ones. Meanwhile

Herr Varrentrapp, of Brunswick, experimented in his laboratory to the same end. He caused a current of air, free from carbonic acid, to pass through a vessel containing moist coal, and thence through a solution of baryta. Carbonate of baryta was precipitated. The fact was thus established that at ordinary temperatures oxidation of the coal and the formation of carbonic acid took place, and that the quantity of the latter was much increased by raising the temperature. He found also that in three months, with the heat kept uniformly at 284° Fah. (140° Cent.), all the *carbon* in the coal had passed off as carbonic acid. And yet this degree of heat is far less than is sometimes evolved in great heaps of freshly mined coal. These experiments went to confirm the results first obtained by Herr Grundmann. The latter, in his new experiments, takes small coal, with no pieces more than two inches in diameter, of three different kinds, and got from three different mines. Of them he makes, in the open air, three separate heaps from 4 ft. to 5 ft. high, and 20 ft. to 30 ft. in diameter at their base. The coal was the best coking and gas coal in Upper Silesia. From time to time during the year of exposure, average samples, selected with the greatest care, were taken for rigid and accurate analysis. Large coal, in pieces of 3 lbs. or 4 lbs. weight, was also included in the investigation, but it was kept under cover and not exposed as were the heaps of small coal. It is unnecessary to give in detail the mode of proceeding. It is enough to know that no labour was spared to ensure entire accuracy. The results fully confirm the correctness of his former experiments, and his conclusions may be briefly stated as follows: That, during the period of exposure, the coal underwent a process of slow combustion, taking up oxygen and giving off the volatile products of oxidation. In this decomposition air and moisture play the principal part, and warmth is the condition promoting it. The degree of heat determines the rapidity of the process. The heat developed may be sufficient to ignite the inflammable gases, as is not unfrequently shown by the spontaneous combustion of large heaps of coal, and by the fires in the mines themselves. That the decomposition was the same in the interior of the heap as on the surface; it being equally rapid at both points. That the action was most rapid during the first few weeks of exposure, the heat generated by decomposition reaching its maximum about the third or fourth week. That one-half the oxygen absorbed was taken up during the first fourteen days. The well-known rapid heating of freshly mined coal, and the fact that coal long mined is far less liable to spontaneous combustion, may be adduced as corroborative evidence of this. That a coal originally poor in oxygen decomposes more rapidly than one rich in it. That coal dried at a temperature of 212° Fah. till its weight remains constant can be heated up to 392° Fah. (200° Cent.) without further loss of weight. Hence moisture is an active element in the decomposition. That large coal, exposing less surface to the action of air and moisture than small coal, is much less rapidly decomposed. The tendency, however, of large lumps having joints to fall to pieces on exposure is well known. The analysis of the freshly mined coal of the several heaps gave the following composition :

	I. per cent.	II. per cent.	III. per cent.
Carbon	76·51	78·32	81·21
Hydrogen	5·32	5·04	5·38
Nitrogen	0·92	0·88	0·89
Oxygen	5·83	8·08	5·72
Sulphur	1·08	0·66	0·77
Ash	10·34	7·02	6·03
	100·00	100·00	100·00

The results of the experiments are as follows :—

SMALL COAL IN HEAPS.

	I. per cent.	II. per cent.	III. per cent.
Absolute loss of weight	33·08	44·61	42·19
Loss of value as fuel	47·69	56·81	55·38
Loss of value for gas	45·51	47·95	50·29

LARGE COAL KEPT UNDER COVER.

	I. per cent.	II. per cent.	III. per cent.
Absolute loss of weight	10·69	6·36	3·19
Loss of value as fuel	12·59	9·04	4·66
Loss of value for gas	23·93	16·22	14·24

The great deterioration in quality of the coal from exposure to the weather is thus most conclusively shown. It consists in the loss of the valuable combustible ingredients, and a relative increase of the injurious ones—sulphur, oxygen, and ash. The coking quality of this weathered coal was also carefully determined. The three coals yielded, when freshly mined, a firm, coherent coke, of very good quality. After exposure their character was quite changed. One of the coals at the end of eleven days yielded no coherent coke at all, while from the two others a coke was got, but of quite inferior quality, and the longer the coal was exposed the poorer was the coke. For gas purposes also, the weathered coal had seriously deteriorated, as the above figures show. That they are not exaggerated it is only necessary to instance an experiment made with considerable quantities of coal at the gasworks at Kattowitz. The coal yielded, when fresh, 1,348 cubic feet of gas to the ton. During one month a quantity of the same coal was kept in bins under cover, and another portion exposed without cover. The yield of the former was 1,116 cubic feet, and of the latter 950 cubic feet per ton. Here there is a loss in a single month in the sheltered coal of 17·21 per cent., and in the exposed portion of 29·52 per cent. In view of these facts it would seem to be the interest of the miner and dealer in bituminous coal to see to it that the coal be kept from exposure as far as practicable, that it should never be piled in heaps while wet, and never in great quantities even when dry. And these are points in which all gasworks and other consumers of this kind of coal are more especially interested, for they must in the end pay for this waste of combustible material. That this subject of protecting a valuable fuel so liable to deterioration has not met with the attention its importance deserves, must be evident to any one who has observed the great heaps entirely unsheltered in the coal yards of many of our large cities."

26. *Monmouthshire Steam Coals.*—"About three years ago," says the "Practical Mechanics' Journal," "when the celebrated trials took place as to the relative merits of Welsh and north country coals, certain regulations were laid down by the Admiralty authorities which practically excluded Monmouthshire steam coal proprietors from competing for navy contracts; and, as a natural result, the price of the coal in the open market was also affected. It is well known that coal not on the government list is always put down as a relatively inferior article, and hence it is not surprising that the colliery proprietors of Monmouthshire at once took steps to obtain a reversal of the regulations referred to, and which in

reality amounted to a virtual denial of the right of Monmouthshire steam coals to be on the government list. A memorial was got up in reference to the matter, which stated that the steam coals of Monmouthshire were known as bituminous, and for economic value and evaporative power were fully equal to north country coals. In June and July, 1863, trials were made on board Her Majesty's ship *Fearless*, the results shown being that while the consumption of Monmouthshire coal in the production of the same indicated horse-power was in one case 40 per cent. and in another 20 per cent. less than that of the north country coals, the former produced smoke in a medium volume of light colour, and the north country coal emitted large volumes of black smoke. This memorial was signed by the leading colliery proprietors of the county, and a reply has just been received from the lords of the Admiralty stating that the restrictions will henceforth be removed, and instructions to that effect have been given to the proper officers. The decision arrived at has given great satisfaction, and the result will be that the Monmouthshire and north country coals will in future be placed on the same footing as regards navy contracts."

27. *Peat Fuel.*—In our volume for last year, at p. 125, we gave Mr. Hodgson's paper upon Peat Fuel; as bearing upon the subject we give the two following articles from the "Scientific American:"—

(*a*) *The Origin and Composition of Peat.*—"Whatever dispute there may be as to the origin of coal, there can be no valid question that the composition of peat is mainly vegetable. The evidence of this is of a *prima facia* character; for even those varieties which appear to the unaided eye but masses of smooth, oily muck, show, under the microscope, the remains of minute mosses, which flourished and died through countless generations, and sank below the water which sustained and supported them while living.

On many a plain, on lofty table lands, in gorges and valleys, wherever water gathers, from a thousand sources miniature pools or extensive morasses are formed by the water being held stagnant and imprisoned by the solid clay or hard rock beneath.

On the surface of these silent waters confervæ, so minute as to be visible only as a green scum, appear, live their brief life and sink to the bottom. Others immediately take their places, live and die, until film after film is deposited. In time this very gradual accumulation becomes a palpable mass; not, indeed, until countless generations of these confervæ have lived and died. Particles of sand and stones gather and are held; the decaying roots of adjacent plants, killed by the sluggishness of these waters of death, help the accretion of the mass. It rises year by year until it affords a foothold for water fowl, which add their qualities of guano, and at last it covers the dark waters and forms a peaty mould extending to the surface.

These changes have been passive; but the water still accumulates, and at length becomes aggressive, breaking through the felt-like mass and destroying the daring vegetation that attempts to procure a foot-hold over the treacherous slime. Below all is the water; next, the black peat, composed of these almost invisible confervæ; then the closely interwoven mummies of roots, which make the surface turf, or peat.

Vast regions of the globe called by geographers 'solid land,' are covered by these peat bogs, or treacherous morasses. The table lands of the South American Cordilleras; the immense plains of frozen Siberia; about one-tenth of the island of Ireland; large parts of Scotland, Germany, Jutland, Norway; the gorges and valleys of the Alps, and innumerable localities on this continent, are occupied with these moors. Within the limits of the polar circle and under the burning sun of the tropics they exist and increase. They do not rest. Their quiet is only apparent. The slow but sure progression of the moor is insured by the increase of water and the accumulation of decayed and dying vegetation; so that at times the air and gases, imprisoned beneath the tangled network of roots and fibres and the coat of deceptive turf, assert their right, and burst all restraints, sending forth streams of black, liquid mire, which overwhelm or destroy all within their reach.

But the silent and almost unobserved action of these peat marshes is not less remarkable. Quietly, gradually, but irresistibly as fate itself, wherever they exist, they exist but to destroy. They undermine the roots of proud forest trees and sink them, still upright, in their miry depths, beyond the reach of sunlight and air. Or, they cut them down, and swallow roots, branches, and foliage beneath their insatiable waters.

Water either in motion or at rest is a great destroyer. Where the solid land or dense vegetation does not offer a bar to its aggressions, it comes in to usurp and reign. We have in our recollection one notable instance. In provincial times a large tract in the little State of Rhode Island was a thick cypress or cedar swamp, the resort of innumerable animals as wild as their habitation. The trees were cut down, the vegetation killed by fire, and the waters came in, and now the tract of salt water, called 'Hundred Acre Cove,' covers thousands of acres, and affords fine fishing grounds, rendezvous of water fowl, and a magazine of fuel and fencing material by its wealth of stumps and roots.

What are commonly known as salt marshes are now or are becoming beds of peat. The accumulation is very gradual, the growth of one season forming a thin layer to be succeeded by another. The rank grasses, rushes, and other water plants and the shrubbery, which retains a precarious foothold on the surface, add to the mass year by year. In time what was a treacherous morass becomes apparently *terra firma*, and more advanced forms of vegetation take the place of the aquatic growth; a forest rises over a marsh. The marsh, however, is still there, and below the roots of the trees is a spongy bed of peat. The sea itself holds in its relentless grasp vast deposits of this substance, destined perhaps hundreds of thousands of years hence, to furnish fuel and light to other races of men. The sea in many places is making encroachments on the land, or rather the land is sinking below the sea level. Where, as in the case of the 'Hundred Acre Cove,' the barrier to the sea has been removed by human agencies, the ocean has usurped and held dominion.

Even beneath the shade of forests growing on solid ground, peat has formed and is in process of formation. The foliage of the trees, with the countless shrubs that grow in dank luxuriance in the impenetrable shade, decay, and form layer after layer of soft, slimy substance which becomes in time concreted into genuine peat. Thinning the forest dries the soil, and in time the peat is a dry, fibrous substance, naturally prepared for the use of fuel."

(*b*) *Manufacture and Combustion of Peat.*—"Peats differ in colour, weight, degree of decomposition or transformation, in purity, and richness or value for fuel. Grass peat is greyish in colour, and moss peat of a reddish hue. That formed from shrubs is generally darker. These are the surface hues; as we descend, if the deposit is deep, the peat changes to very dark brown or black. Surface peat is usually light and fibrous. It is neither living vegetation nor perfected peat, and is unfit for fuel. The peat below the surface is soft, pliable, and when moist can be easily moulded; it is fine in grain, oily to the touch, and has no perceptible odour. If it shows sand or clay when dried, it is not valuable as a fuel. To be profitable it should not, when consumed, leave more than one-fifth of its weight in ashes. Some very fine specimens do not leave over one-fortieth of ashes.

The author of a little treatise entitled 'Peat,' published by J. H. Benham, New Haven, Conn., says: 'Peat possesses elements and qualities like coal. As manufactured by the present improved machinery, the actual heating power is two-thirds that of coal, while for the generation of steam it is, by its abundant blaze, fully equal to coal. It has qualities peculiarly adapting it to manufacturing purposes. Improvements in machinery for its preparation, to which the best scientific minds in the country are now turned, will, we doubt not, soon enable manufacturers so to condense peat as to make it, with its other excellent qualities, superior to coal for many purposes. It can be prepared and brought to market at a profit, for less than half the present cost of coal.'

The deposits of peat fuel have been utilized from time immemorial. The Irish have depended upon them for fuel for many generations. In some countries the turf has been used as a material for constructing habitations, as well as for the furnishing of fuel. In this country peat has been used almost ever since its first settlement as a fuel. The first settlers discovered, as early as 1690, the value of their peat beds as a means of warming their houses and cooking their victuals. When wood was plenty and easily cut they preferred that, but there are not wanting evidences that our forefathers, in colonial times, knew that peat was a valuable, or, at least, a feasible substitute for the plentiful wood pile. We can well recollect when, with team and wagon, we were sent to the adjacent 'peat bog' to bring home the results of the summer cutting, and loaded into our wagon the blocks of air-dried peat. They were cut out from the mass with a spade called a 'slane,' having a side and edge turned at right angles, so that the workman separated at each pressure a complete block. These were built into cob-houses, allowing the air to pass freely through, which dried the turf, until that quality which was the most porous assumed a light-brown hue, and was as light as cork. The more solid qualities were heavier.

We never burned the peat in a confined air space, as a stove or close grate, but we have seen it used in an open fireplace instead of wood. In these situations it burns as fine as the best walnut. It gives out a genial heat without sparkling or throwing out splinters, and retains fire long after it has ceased to blaze. For this reason, we judge, in our juvenile days the late hours in the evening were enlivened with the glare of burning peat, which held the fire until the next morning.

But lately, since the people have been aroused to the value of their peat beds,—a value which we cannot but think has been in some cases overrated,—various means have been invented for condensing the turf and for burning it with economy. One means of preparing it for the market, and for economical use as a fuel, is that of treating it as clay for bricks is treated, by grinding it to an almost impalpable pulp, or powder, and then compressing it by mechanical agency, finishing by drying it by artificial means. This, even by the most rapidly working machines, is costly,—especially the artificial drying. Another plan is to agglomerate and condense the material by mechanical means and then subject the blocks thus formed to the action of the atmosphere. The result is excellent.

There can be no doubt of the value of peat as a fuel, either for domestic or manufacturing purposes, when properly prepared; and where the place of consumption is near the place of production, and away from the sources of coal supply. Merely cut and dried, however, it still contains about 20 per cent. of water, sufficient to greatly lessen its value as a fuel. Disintegration and compression seem to be necessary to rid the substance of this surplus moisture. Baking it, or partially coking it, by expelling the moisture, greatly enhances its value. Even the 'grinding,' or thorough mixing of the mass, aids in the expulsion of the water, and peat so prepared and afterward air-dried is greatly improved. The best results, however, are obtained by subsequent compression, and, if possible, a thorough after-drying.

Peat can be burned as wood on an open hearth, or as coal in an open grate. It can be used under the furnaces of engines adapted for burning either anthracite or bituminous coal; but in neither position do we think it is superior to mineral coal. For manufacturing purposes, when used in combination with iron, it may be less deleterious to the metal than uncoked coal; but we much doubt whether it will ever usurp its place until coal shall become scarce in this country, which will not be in this nor in several succeeding generations.

On the whole, we believe peat to be valuable where it can be prepared and used near the point of production, but notwithstanding the reports we have seen in its favour as a substitute for coal, in heat-producing qualities, as in the running of locomotives, etc., we believe it is far below mineral coal as a fuel. While wood and coal, our ordinary fuels, rule so high in the market, it may be found profitable, both to manufacturer and consumer, to enter it as a competitor. It can be said that no fuel now used requires less skill in its management or gives a more genial heat for domestic and household purposes."

28. *Petroleum and its uses as a Steam-Generating Fuel.*—As will be observed on referring to our two last volumes, the use of petroleum for furnace purposes has been one of the subjects which has been attracting the attention of practical men for the last two or three years. In connection with this, and as indicative of the present position of the question, we give the following paragraphs from the various sources named; preceding them with one (*a*) from the "Scientific American" as to the nature and analysis of petroleum.

(*a*) *What is Petroleum?*—The crude petroleum of Pennsylvania always issues up out of the earth mixed with inflammable gas. This gas makes an excellent fuel, and is much used for generating steam for the pumping engines. It is abundant enough to run all the engines in the oil district.

If the gas, as it issues out of the wells, be subjected to pressure, or to a temperature of zero, a considerable percentage of it will be condensed into a liquid, the amount condensed being somewhat proportioned to the pressure and cold. Some of it, however, refuses to condense at any pressure and cold which we can command, and such is consequently a permanent gas. That which condenses assumes the form of gas again as soon as the pressure is removed and it is exposed to ordinary temperatures. The change into gas or vapour is very rapid and violent, and in fact is a case of boiling. Some of the volatile liquids will boil on ice!

It is evident from these statements that petroleum gas is in fact a mixture of several gases and vapours, which may be separated from each other by careful management of pressure and cold.

We may likewise demonstrate the fact that the liquid crude petroleum is a mixture of different liquids. The partial separation of these may readily be effected by distillation. The oil which first appears on distillation is very light in gravity, and has a low boiling point. As the distillation progresses the gravity and boiling point increase with remarkable regularity; from the beginning to the end there appears to be a constant and regular progression.

The reader is now prepared to apprehend the fact that petroleum is composed of a *series* of substances having properties which differ from each other only in degree. There is a beginning and an end, or top and bottom of the series, and between them regular gradations of intermediates. The beginning or top of the series is a permanent gas; the bottom or end is a solid. Between these are gradations of consistency, gravity, and volatility.

In an arithmetical or geometrical series there is always a peculiar difference between consecutive members of the series: given one member of the series and that peculiar difference, and the whole series may be determined, or any particular member of it. Is there any such certain and interesting relation between the members of the petroleum series?

The only chemical elements which enter into petroleum are carbon (C) and hydrogen (H). (Water, sulphur, nitrogen, compounds, etc., which are often found in crude petroleum, are properly regarded as foreign substances.) Now it is evident that the members of the series must differ by varying proportions of these elements—there must be progressive increase of one over the other.

The beginning of the series has been found to be composed of two atoms of carbon (C_2) with four atoms of hydrogen (H_4); the beginning of the series is represented thus—$C_2 H_4$. Now happens that this substance $C_2 H_4$ to chemists is a familiar acquaintance. It is commonly known under the name of *marsh gas*, and is known to coal miners as fire-damp. The second member of the series is $C_4 H_6$, and the third is $C_6 H_8$. The reader hardly needs to be told that the fourth is $C_8 H_{10}$, and he is able to determine the twentieth. The common difference of the series is $C_2 H_2$, and the general formula for the series is $C_n + H_{n+2}$.

We append a table showing the specific gravity and boiling point of a part of the series. The first four are gaseous at ordinary temperatures, and the specific gravities are given in comparison with air :—

		Specific gravity.	Boiling point.
1.	$C_2 H_4$	0·554	...
2.	$C_4 H_6$	1·04	...
3.	$C_6 H_8$	1·52	...
4.	$C_8 H_{10}$	2·01	32°
5.	$C_{10} H_{12}$	·628	86°
6.	$C_{12} H_{14}$	·669	158°
7.	$C_{14} H_{16}$	·699	198°
8.	$C_{16} H_{18}$	·726	243°
9.	$C_{18} H_{20}$	·747	278°
10.	$C_{20} H_{22}$	·757	321°
11.	$C_{22} H_{24}$	·766	359°
12.	$C_{24} H_{26}$	·766	408°
13.	$C_{26} H_{28}$	·792	423°
14.	$C_{28} H_{30}$	·800	460°
15.	$C_{30} H_{32}$	...	496°
16.	$C_{32} H_{34}$	...	527°
17.	$C_{34} H_{36}$	·825	...
25.	Paraffine	·870	...

(*b*) *Petroleum for Steamers.*—"Calculations of the relative economy of coal and oil as fuel for ocean steamers, should take into account the important item of firemen and coal-passers, their wages, weight and quarters, in addition to the difference in weight and space of furnaces and perhaps of boilers. In the recent experiments on board the *Palos*, at the Charlestown Navy Yard, it has been found that with three of her four boilers, and the attendance of three men, fifty per cent. more revolutions of the wheels were obtained than heretofore with coal under all four boilers, with the attendance of twenty men. But the greatest probable difference may be realized from a more perfect utilization of the force contained in the fuel. It is well known that as yet but a small percentage of the theoretical power of fuel has been obtained through steam. Coal heat is mostly applied by radiation. Oil, with proper apparatus, may be brought, in a state of combustion, mainly into direct contact with the boiler surface. How great a difference this may effect in practice can be determined only by proper experiment. So that the question between coal and oil cannot be ciphered out entirely from theoretical data.

In this experiment petroleum was the oil supplied from two large iron tanks placed on deck, each tank having a glass gauge at its side, to indicate the height of the petroleum, and a vent-pipe on the top to permit the escape of vapour. From these tanks the petroleum was conducted by half-inch pipe to the boiler furnaces, dropping into iron retorts, heated by burners placed beneath them, and being instantly vapourized. This vapour, in burning, was mixed with steam—decomposed by passing through pipes partially filled with iron filings, and with air forced in by a common air-pump. The heat thus generated was intense; and the combustion was so perfect that no smoke was perceptible. A diminution of the supply of air or steam at once created a smoke.

Commodore Rodgers, commandant at the yard, is so well satisfied with the three days' experiment, that he has determined to apply to the department at Washington for permission to make a trial trip at sea with the *Palos*."

The following is in connection with the trip here referred to, for which we are also indebted to the "Scientific American:"—

(*c*) *The Petroleum Trial.*—"The first experimental trip of the *Palos*, June 14th, with petroleum as fuel, resulted in a total run of 25 nautical miles in 1 hour and 55 minutes, or a little over 13 knots an hour. The reported result is almost incredible, as the *Palos* is only an 8-knot steamer, with coal. Four barrels of oil were consumed on the trip, doing the work of eight tons of coal. The oil drips into a hot iron retort, where it is converted into gas and mingled with steam and air in exact proportions to produce entire combustion and the most intense heat, which distributed to the heating surface of the boilers with such effect as to raise steam in 25 minutes, where three hours were required with coal. Such is the case thus far, as made out by the friends of the improvement.

We add the following letter from Engineer Alban C. Stimers relative to this interesting trial and the subject of petroleum for fuel. It was addressed to the New York *Times*:—

NEW YORK, *Monday, June* 17, 1867.

I observe in your editorial remarks in minor topics, in adverting to the Boston petroleum fuel experiments, in this morning's paper, an inquiry regarding 'the original source of the steam that is taken from the boiler and passed into the retort that generates the vapours that make the heat that raises the steam in the boiler.'

Having closely observed the various efforts made during the past five years to employ petroleum in lieu of coal for a steam fuel, I take the liberty to offer the following explanation in reply to your inquiry.

The introduction of superheated steam into the retort where the oil is vapourized is not essential to the making a fire and getting up steam, but it is to burning said vapour with the completeness of combustion necessary for it to compete with coal as a steam fuel. In burning the vapours of petroleum it is necessary that every particle of the vapours shall come into close contact with a corresponding particle of atmospheric air; but air and the vapours of the oils appear to have the same repellant qualities as oil and water, and do not mix enough to prevent the formation of a thick black smoke, and the heat developed is comparatively very small.

All who have attempted the use of petroleum for a steam fuel, appear to have early learned the great advantage of introducing superheated steam to the vapours. When this is done, the air mixes readily with the compound, and a more complete combustion is effected.

Although, as I have already stated, steam could be raised in a boiler from burning the oil vapour only, yet it is done much more quickly and pleasantly if a supply of steam can be had, and I observed that on Friday last the fires of the *Palos* were assisted with steam from a sister vessel, the *Leyden*, which lay alongside.

The first experiments tried to test the practicability of employing petroleum for generating steam were by Shaw and Linton, in Philadelphia. I was member of a board of naval engineers, ordered by the Department to conduct and report upon the experiments. They continued during five months, and our report is dated May 5, 1863.

In that arrangement, 'the apparatus used was an ordinary tubular locomotive form of boiler containing fifteen tubes, two inches in diameter and fifty-six inches in length; a small steam engine, in connection with it, operating a pump supplying water to the boiler; with an additional boiler of very small dimensions, placed in a heating apparatus, to provide a steam jet, previous to firing up with the oil, in the absence of other means for procuring the necessary artificial draft until steam was raised in the larger boiler.'

This would be a good arrangement for Colonel Foote to employ with his process. The great merit of Colonel Foote's process over all those which have been tried in this country and in England, consists in his forcing the air, necessary for the combustion of the oil, directly into the retort where the latter is vaporized, and as super-heated steam is introduced simultaneously, *the air becomes thoroughly mixed with the vapours before they issue from the burners*, and the combustion is consequently perfect when the proper proportions of air and oil are maintained. This desideratum is never attained in any other process yet brought to my attention.

When an inventor comes to me and describes the brilliant white flame which he produces with his greatly improved petroleum burner, I know that he cannot compete with anthracite coal in economically generating steam. And Colonel Foote is the only one who has shown me a fire where all that was visible was the blue hydrogen flame, which every chemist will understand is—with such a combustible—the hottest attainable fire."

The same Journal has the following:—

(*d*) *Petroleum as Fuel for Locomotives.*—"The Titusville *Herald* describes the fourth of a series of experiments made at the shops of the Warren and Franklin Railroad at Irvine, as follows:—'The apparatus used was Spencer's burner. It is described as consisting of a pan covering the bottom of the firebox in the locomotive, and taking the place of grates. On the pan are placed heaters or gas-generators, six in number, consisting of inclined plates of cast iron supported at an angle of forty-five degrees. Opposite to each heater is an injector, conveying the oil to the heater, where it is instantly converted into gases, oxygen being only furnished to the gases in their nascent state for combustion. The oil is contained in a tank on the tender, from which it is conveyed by feed pipes to the injectors, each pair of injectors being controlled by a throttle by means of which the fire is regulated as readily as the light of a lamp. The locomotive used weighed thirty-one tons, and was of one hundred and fifty horse-power. No cars were attached. Under eighty-five pounds of steam the locomotive passed over four miles of track in less than eleven minutes. All in the party agree that oil may supersede wood and coal in railroad use.'

There is at present no better field for invention than the contriving of furnaces for producing combustion safely and economically from petroleum. Also, in the feeding from and construction of tanks for conveying the liquid."

29. *Pulverisation of Liquid Fuel.*—"Captain Schpakovski, Professor at the Russian Military College of Paul, has recently made some very curious experiments on certain applications of the 'power of liquids,' or, in other words, on water, alcohol, turpentine, naphtha, and other substances, in a very finely divided condition. The advantage obtained by such minute subdivision is the obtaining complete combustion of the whole of the carbon contained in the liquid. The Captain has constructed a peculiar lamp, which may be regarded as the typical instrument of his system. The flame of this lamp, fed by turpentine, rises to the extraordinary height of two feet, and it issues from the burner with a noise that resembles that caused by the rush of steam out of a pipe; its colour is yellowish-white, and its temperature is that of the fusing-point of steel. The quantity of turpentine consumed by the lamp in connection with the pulveriser is from two to five pounds per hour. Captain Schpakovski commenced his public experiments with the fusion of fine steel wire, which, after a few seconds, began to melt and burn away in

sparks. He then gave the flame a horizontal direction, and melted a piece of copper. He also exhibited a crucible, intended, with the aid of the pulveriser, to melt pieces of copper weighing from five to ten pounds. The application, to which Captain Schpakovski attaches the greatest importance, however, is the heating of the boilers of steam-boats. He has constructed a small vessel, 24 feet long and 5 feet wide, with an engine of two horse power, which performs 6½ knots an hour. The boiler is heated by four pulverisers, the turpentine being stored forward, and conducted through a tube, furnished with a regulator, to the pulverisers. The consumption of the liquid is stated to be equal to three pounds per hour per horse-power. The Captain is now engaged in the construction of a vessel of three times the above power, and he expects, in consequence of improvements in the boiler, to be able to reduce the consumption to about half the above amount. It is said that orders for twenty steamers for St. Petersburgh and the neighbouring places have already been received, and that it is proposed to establish communication, by means of small vessels on Captain Schpakovski's principle, on the Neva, between the town and the islands, so that passengers may be conveyed through the canals of the Moika and of Tontaka to the central station on the Neva, where the large vessels lie that run between that place and the islands. It is not pretended that the heating by means of turpentine will cost less per hour than coals, but, as the former will not require the fires to be lighted more than ten minutes before starting, there will be a great economy in the case of very short runs like those on the Neva, which only occupy about half an hour. The new method is also applied to night signals, the lantern giving three times as much light as those at present in use."—*English Mechanic.*

30. *Liquid Fuel in Combination with Steam for Steam Generating Purposes.*—From a very interesting paper, under the title of "Liquid Fuel," in "The Engineer" for March, 1867, we extract the following, descriptive of two modes of using liquid fuel in combination with steam:—"The application of steam in the same manner, and its use simply as a fuel in conjunction with coal and other solid fuel, is by no means new, but we are not aware of any tangible economic results therefrom, or that the practice has anywhere been permanently adopted from its

being known to effect a positive saving in coal. The action of steam in combination with *liquid* fuel, however, may possibly be of a much more advantageous nature, and a positive gain be established by the expenditure of a portion of the steam generated. Whether this be the case or not, we have not yet sufficient data to decide, but the use of the steam jet is otherwise essential to both the systems which we are about to describe, viz., that of Mr. Richardson, of which some notices have already appeared, and that of Mr. Harrison Aydon, patented last year under the names of Wise, Field, and Aydon.

Supposing we were to admit the full performance of 19 lb. of water evaporated by 1 lb. of fuel to be all pure gain, without making any deduction for the steam employed, were there no modification in the nature and cost of the article proposed to be used, we should still be so far from the region of possibility as regards the practical application of petroleum, that the subject would be unworthy of serious attention; but both the present experimenters, particularly Mr. Aydon, have turned their attention to the use of creosote and other substances more or less the refuse of previous distillations, and at present at least of very small value. Besides, the price of petroleum and shale oils has considerably fallen, that of the crude petroleum operated upon in Mr. Richardson's last trial at Woolwich being set down at £5 per ton, and that of once run oil at £10. But of the practicability of ever using so expensive an article as this last, even in small admixture with cheaper substances, we are altogether sceptical.

The fuels tried by Messrs. Field and Aydon so far have been only dead oil of tar, a liquor remaining after the extraction of some of the hydrocarbons from coal tar, and a semi-fluid substance which remains after the extraction of paraffin from coal oil. The latter article has been sent up from Liverpool by manufacturers who are at present only desirous of getting rid of it at any price, and certainly any one who saw its combustion proceeding, as we did in the Cornish boiler at Messrs. Field's candle factory, would have no hesitation in saying that the desired object had been fully accomplished. The value of the creosote, or dead oil of tar, used in both the Woolwich—Mr. Richardson's—and the Lambeth—Mr. Aydon's—experiments, is stated at from 15s. to 20s. per ton. We believe that at present it is a drug in the market, and might be obtained at a nominal cost; but we doubt if there are sufficient sources for the supply of any very large demand. Mr. Richardson's method of using petroleum oils and other fluid substances as fuel has already been noticed in THE ENGINEER, and the particulars of a series of experiments made at Woolwich last summer under the inspection of the authorities there have subsequently been given. The plan which he adopts consists in using a fire-grate, or rather hearth, of porous clay, and in supplying the oil by one or more channels running longitudinally through this block of porous material; the oil permeates the mass, and rising through it is rapidly volatilized, burning constantly as a gas in the furnace. He now uses jets of steam entering with the oil and rising with it through the material.

The introduction of steam into the fire-space is an absolute necessity in burning oils on this plan, for without it the quantity of smoke and soot produced would be unendurable, and the loss of carbon carried off in this way would reduce the calorific effect of the fuel to a point very low; but as the steam is rapidly decomposed in the high temperature of the furnace, its hydrogen constituent takes up this escaping carbon by a powerful affinity, and, as already observed, gives rise to new heats produced by combinations with the oxygen of the atmosphere.

We understand that Mr. Richardson first introduced the steam directed by a jet into the fire-box, and that the modification of introducing it with the oils by channels in the porous hearth was a subsequent improvement, leading to his application for a second experiment at Woolwich, which terminated on the 11th ult. He has furnished us with the following particulars on the subject:—

'The petroleum boiler at Woolwich has four fire-places, each 3 ft. 3 in. in length, 12 in. wide, and 10 in. high, too small to allow of any quick or great combustion of fuel, or to allow the steam jet full action. The steam jet to each fire-place is one-eighth in diameter, and seldom can be turned on more than a quarter full. The smoky oils require a greater amount of steam than can be given them in these fire-boxes.

To start the boiler oil only is used, not coal. The rule is to begin with thin liquid oil, such as once run; when steam is up to 10 lb. pressure, the fires are turned down, and the tubes swept; this done the fires are again put on, and the steam jets applied gradually, increasing the supply of steam till all smoke has disappeared. Two only of the four fire-places are arranged with the latest improvements. One of the remaining two is defective from a leak in the boiler, and in the other the steam is not admitted in the way which I have found to be most beneficial. The experiments from the 5th to the 11th inst., inclusive, were conducted in the two first-named fire-places only, which had a total grate surface of 8·94 ft., and the total fire-box and tube surface corresponding to these grates was 157 square feet. The results of the experiments were as follows, viz.:—

5th February, 1867.—4,500 lb. of water evaporated, at the rate of 10·81 lb. of water to 1 lb. of oil. Eight hours' trial. Thick black smoke.

6th February.—4,000 lb. of water evaporated, at the rate of 12·42 lb. of water to 1 lb. of oil. Eight hours' trial. Smoke very moderate.

7th February.—3,500 lb. of water evaporated, at the rate of 12·15 lb. of water to 1 lb. of oil. Six and a-half hours' trial. Smoke moderate. Creosote and shale oil mixed used.

8th February.—3,500 lb. of water evaporated, at the rate of 13·67 lb. of water to 1 lb. of oil. Seven hours' trial. Smoke moderate. Creosote and heavy oil used.

9th February.—4,000 lb. of water evaporated, at the rate of 16·12 lb. of water to 1 lb. of oil. Six and a-half hours' trial. Once run oil used. The fires burnt clear and bright, and required very little attendance.

11th February.—3,500 lb. of water evaporated, at the rate of 18·91 lb. of water to 1 lb. of oil. Creosote used only. Smoke moderate, but very thick and black when the oil was run in too quickly. The tubes moderately foul at end of trial. 6·5 minutes' trial.

The various fuels used were Burslam, once run, sent by J. Slater; once run and crude from Plas-yn-Mhowys, near Mold; and common creosote, from Bow. The value of the crude oil is £5 per ton; once run £10; and creosote from 15s. to 20s. I have yet another fuel to test, naphthaline, more powerful than creosote, and less in price.

The boiler had not been used for seven months previous to this trial. All the gentlemen who visited it during the experiment expressed it as their opinion that it was too small to allow the process to be properly carried out. I have asked permission to use a common marine boiler to test these fuels thoroughly.'

It is much to be regretted that both this experiment and the first Woolwich trial of Mr Richardson's system were made in a boiler clearly unsuited to the fuel; less suited, in fact, than a tolerably well-constructed marine boiler would be. It seems to us quite possible that the smoke, which was not altogether obviated when creosote—the cheapest fuel—was used, might have been beneficially consumed had the fire-box been larger. It is also stated that, with a larger fire-box more rapid combustion would be obtained, and therefore an increase in the evaporative power of the boiler in proportion to its heating surface. It will be seen from the data of the foregoing experiments that such an improvement would be essential to the success of the system, for the quantity of water evaporated per foot per hour in these trials has not been up to what the performance of a marine boiler should be. It is essential in applying Mr. Richardson's system, that the boiler should have a water-space under the ash-pit, for upon this he lays his porous fire-grate, which speedily becomes red hot, and would soon be destroyed, besides burning any iron plate on which it rested, if the heat were not constantly abstracted by a surface in contact with the water of the boiler. Otherwise we see no obstacle to the application of the liquid fuel burner to any boiler of good construction, or even to its occasional substitution for coal-burning arrangements, without much expense.

The plan adopted for burning liquid fuel by Mr. Aydon, and now in operation at Messrs. Field's works at Lambeth, differs essentially from the above, and is characterized by much originality in conception. To describe it in a few words, it consists in the application of Rimmel's scent distributor to the injection of liquid fuel into the fire-box, and its intimate mixture with superheated steam. The creosote or oil in use is held in a small tank placed a foot or two over the fire-door, and a steam pipe is led through it to keep the oil in the necessary state of fluidity; from a cock in this cistern a thin stream of oil is kept running into a funnel, which conducts it to a point in front of the fire-door, where it comes in contact with a jet of highly superheated steam, and is carried into the furnace in the form of spray, intimately mixed with steam of a very high temperature. The ordinary fire-bars are covered with a layer of cinders, which remain red hot but do not sensibly decrease, and a block or bridge of fire-brick is placed across the furnace, rising considerably higher than an ordinary bridge. Against this block the entering jet of steam and oil is directed, and is dispersed in all directions as it strikes it, bursting into a splendid hydro-carbon flame, which can be extended by the judicious management of the air and gases to almost any length.

The quality of the flame leaves nothing to be desired, and in volume it can be regulated to a nicety. The experiments hitherto tried in Messrs. Field's factory have been limited to some tests of evaporative power, and the still more practical one of working the factory engine with the boiler raising steam in the manner above described, but we are not in possession of such data as would enable us to give the rate of evaporation per foot of heating surface per hour, or to specify the number of pounds per hour of oil that may be burned in a fire-box of a given capacity without generating smoke.

The only liquid fuel hitherto tested for evaporative efficiency has been creosote, which Messrs. Aydon and Field found to give a duty of 19·5 lb. of water evaporated per pound of fuel used. When we saw the boiler at work, coal-oil refuse, after extraction of paraffin scale, was undergoing a trial, in which Mr. Aydon considered that it was giving about the same duty as that obtained from creosote.

We can ourselves testify to the extreme brilliancy of the hydro-carbon flame in the furnace, and to the complete absence of all smoke, although the boiler, a 10-horse power Cornish, was being rather urged to raise steam quickly for starting after dinner. The two pipes for superheating the steam used in the jet are run just under the crown of the flue, and, therefore, pass through the hottest part of the fire space. We should rather fear a rapid wear in this part of the apparatus, but the other arrangements are exceedingly simple, and no delay worth mentioning would occur in changing from oil to coal-burning, or *vice versa*.

The steam-jet used is $\frac{3}{16}$ in. in diameter, which, at a pressure of

30 lb. on the inch, would perhaps emit one-tenth of the steam generated in the boiler, which is 10 ft. long by 4 ft. diameter, with a 2-ft. flue. The steam thus expended must of course be deducted from the net effective performance of the fuel."

31. *Gas as a Steam Generator.*—We take from the "Mechanics' Magazine" the first two, (*a*) and (*b*), and from "Engineering," the third, (*c*), of the following paragraphs bearing upon this.

(*a*) *Generating Steam by Gas.*—"Whoever has walked through the thoroughfares of our metropolis with open eyes can hardly fail to have noticed bales of goods of every class which are constantly making their slow and tedious ascent from the roadway below to the upper stories of wharves and warehouses. Having observed the facility with which goods are stored in or delivered from our ships by means of steam winches, the observer may have wondered why some such application of steam power was not made to supersede the slow hoisting process going on before his eyes. The simple answer to this is that the insurance companies step in and demand very heavy premiums where steam power is used with the ordinary steam generating apparatus; that is, a boiler and coal-burning furnace. And besides this, the work to be performed is not always of that continuous character which would justify the necessary outlay for an engine of any kind, and the expense of keeping it partially idle. So our wharfingers and warehousemen have been obliged to continue on the old slow system of hand labour, thereby wasting much valuable time, and hindering the course of public traffic by the detention of carts and waggons in the streets. And hitherto there appears to have been no practical remedy on a small scale for this state of things; gas engines and air engines have been tried, but none appear to meet the cases to which we have referred, however well they may be adapted for heavier or more constant work. Now, however, we appear to have arrived at a definite solution of the knotty question, and we hope ere long to see goods make their ascent and descent as rapidly on shore as on board ship. That our hopes stand a good chance of being realised will be seen from the following description of a gas steam generator which we have just seen at work at one of the largest warehouses in Cannon-street.

This very simple and efficient apparatus is the invention of

Mr. Arthur Jackson, of No. 1, Loman-street, Southwark, who has succeeded in perfecting a system of raising steam by gas, which overcomes the objections we have noticed, besides many others which ordinarily attend the use of steam. In the present instance we have a vertical tubular boiler of 2-horse power, supplying steam at 50 lb. pressure to drive a steam crane for raising and lowering goods. The boiler and crane are placed in an upper story of the warehouse, the former being placed on a square slab of stone, and with its polished wood lagging presenting an appearance rather ornamental than otherwise. The feed-water is heated in a casing which is placed round the lower part of the chimney, and the waste heat is thus utilised. So much for the boiler, and now for the furnace—if we may apply the term to a few gas jets. The gas is led from the main pipe to a chamber beneath the boiler, and resting on the stone slab or hearth. Into this receiving chamber vertical burners are fitted reaching nearly to the under side of the boiler and fitted with regulating cocks and air valves. On the top of each burner is a fire-clay disc, the object of which is to spread the flame, and by this means, the whole available heat of the gas is brought to bear on the boiler. A small furnace door of glass or mica enables an inspection of the gas-burners to be made without admitting cold air The regulating cocks also are on the outside, so that the temperature of the furnace can be kept constant.

This apparatus for generating steam by gas heat, of which Mr. Middleton, of the Loman-street Works, is the manufacturer, presents many advantages over the ordinary system. Stoker, brickwork, chimney, firebars, are all done away with, and there is no fear of infringing the smoke nuisance act, for no smoke is produced. Its use is attended with the most perfect cleanliness, as there is no carting of coals nor removal of ashes, no banking up of fires—in fact, no dust nor dirt of any kind. In the boiler we examined, steam was kept up at a steady pressure of 50 lb., with a very small consumption of gas whilst the engine was standing. It only requires a few seconds to kindle the furnace, and it can be extinguished instantly. The consumption of gas we were informed, was 200 ft. per hour with the engine fully at work with 50 lb. steam. This pressure is obtained in twenty-five minutes from the time of lighting, when the boiler has been in use the previous day, and with a consumption of 100 ft. of gas. Steam can be got up to 50 lb. in half an hour from a cold boiler. Besides the boiler we inspected, there are others in use both in London and in Liverpool, all of which are giving thorough satisfaction. In one of these, steam is stated to be kept up for fourteen hours per day for about two shillings, the engine almost constantly going. From what we have stated it will be seen that the hindrances which have hitherto occurred to prevent the use of steam on a small scale exist no longer. Mr. Jackson has overcome them by a system which is certainly the most advantageous we have yet seen for the purpose. It is economical, cleanly, occupies but little space, and affords the greatest convenience to all requiring work of an intermittent character to be done. Not the least important fact is the sanction the fire insurance companies give to its adoption without any increase of premium. Mr. Jackson has supplied a deficiency which has been long felt by the community, and his patent apparatus only requires to be known to ensure its general adoption. Now that the regulation of our metropolitan street traffic is about to become the subject of legislative enactment, it is of the first consequence that our citizens should be enabled in some degree to remedy defects created by trade and commerce. And our subject has an important bearing in this direction, inasmuch as by the adoption of means for facilitating the loading and unloading of merchandise, the public highways would no longer be the standing places for heavy vehicles. At least the time of stopping would be reduced to a fractional part of what it now is, and hence measures less stringent than those which now appear necessary might be found to answer all purposes."

(*b*) *Gas Steam Generator.*—"We have received communications from several of our readers respecting Mr. Jackson's system of generating steam by gas. There appears to be a desire to know the amount of work the boiler in question will perform, the consumption of gas therein, and its evaporative power. The performance of the apparatus was fairly tested last Wednesday, by Mr. Robert Carr, the engineer of the St. Katharine Docks, and we now give the results of the trial. The engine working the lift at Messrs. Cowan's has a 6-inch cylinder and 10-inch stroke, and is equal to 3-horse power, whilst the boiler is only equal to 2-horse power. The rate of working was 150 strokes per minute, and the trial started with 60 lb. steam, when 1,250 lb. were lifted to a height of 50ft. in 30 sec. Eight lifts were then made with the same weight, and, with the lowerings, occupied 6 min. During lifting, the steam fell to 40 lb., but in 2 min. it had recovered itself to 50 lb. Four lifts and lowerings were then made in 4 min.; after each lift the steam fell 3 lb., but recovered itself in 30 sec. These 30 sec. were occupied by the lowering, during which operation steam is not used. The amount of gas consumed was 50 ft. in 15 min.; the trial, we must say, appears highly satisfactory.

With regard to evaporation, we give the following results of an experiment which was made on another of Mr. Jackson's boilers:—1st, 4 gallons of water were evaporated in 30 min., and the consumption of gas was 75 ft.; 2d, 4 gallons of water were evaporated in 26 min. with a consumption of 50 ft. of gas; 3d, 16 gallons of water were evaporated in 1 hour and 26 min., the consumption of gas being 200 ft.; lastly, 8 gallons of water were evaporated in 43 min., for which the consumption of gas was 100 ft. The pressure gauge ranged from 55 lb. to 65 lb., and the temperature of the heat passing out of the chimney was 300 deg."

(c) *Gas-heated Boilers.*—"Although as a fuel for heating steam boilers ordinary coal gas cannot compare favourably with coal, if the cost of the fuel consumed only is considered, yet there are in certain cases many points in its favour which may render its employment advantageous. In the case of very small boilers, for instance, the cost of attendance, &c., bears a large proportion to the cost of the fuel consumed; and it is, moreover, frequently desirable to place such a boiler in a position where the dust and dirt arising from the use of coal fuel would be very objectionable. We have been led to these remarks by having recently seen at Messrs. Cowan and Son's, of Cannon-street, a neat little boiler heated by jets of mixed gas and air arranged according to Mr. Arthur Jackson's patent. The boiler in question was made by Mr. T. Middleton, of Loman-street, Southwark, and it is fixed on the third floor of Messrs. Cowan's warehouse to supply steam to a small engine of about 2-horse power, which is employed for hoisting purposes. It is of the upright class, and has a cylindrical shell furnished with a number of small tubes passing through it from end to end, the upper ends of these tubes being enclosed by a dished plate, from the centre of which a chimney, furnished with a damper, rises. The boiler is seated upon a neat casting, which contains the arrangement of gas jets, the latter being placed a short distance below the lower ends of the tubes. The gas is led by a pipe into a flat chamber fixed on the base plate, and from this chamber rise jet pipes, each furnished with a cock, which deliver the gas into larger pipes, where it is mixed with air. Each of these larger pipes has a set of holes formed in it, through which the air enters, the extent of opening of these holes being regulated by a perforated ring placed on each pipe. Each of the mixing pipes carries a set of burners, arranged like those of a sun-light, and in these jets the mixture of gas and air is consumed, each set of burners having a slab of fireclay placed above them to better distribute the heat. The boiler gets up steam very rapidly, and requires little attention; and when a supply of steam is not being drawn from it, the pressure can be readily maintained just below the point of blowing off by turning down the gas very low, and closing the damper in the chimney. We may mention that the London fire offices have admitted the adoption of this system without requiring any extra premiums on the premises on which it is employed."

32. *Water and its effects on Steam Boilers.*—The following paper, by Mr. H. K. Bamber, was read before the Society of Engineers, March 18th, 1867. After noticing at some length the chemical composition and character of water, as well as its general properties, the author arrived at the description of the different sources from which natural waters were obtained, and also the properties of the water in each case. The author continued: "We will divide the several natural waters into rain, river, well, and sea waters. The principal source of these, except the latter, is rain, snow, or hail. Rain as it leaves the clouds is no doubt almost pure; but in its passage through the air it absorbs certain gases, and carries with it small particles of matter which are floating about in the air. This is the case more especially with the rain which falls first after a long time of dry weather; that which falls after several days of wet being comparatively free from these. The substances thus dissolved

the rain in its passage to the earth are the gases, oxygen, nitrogen, and carbonic acid, a little ammonia, or rather carbonate of ammonia, nitric acid—this latter more especially after a thunderstorm, it being formed from ammonia and water by the passage of the electric spark through the air. The particles floating in the air which are carried down with the rain are for the most part organic. The above would be the principal, if not the only, impurities found in rain-water if it were collected before it had touched the earth, in the open country. In or near large towns, especially manufacturing towns, the case is different. Several other substances would then be found in it, as sulphurous acid, sulphuretted hydrogen, etc., etc., varying with the kind of manufactures carried on near the spot. Again, if rain-water is collected after having fallen upon the roofs of houses, it will be still further contaminated by various substances with which it came in contact, more especially where leaden pipes or gutters are used. This latter contamination is most dangerous where the water is to be used for domestic purposes.

All waters which are free from certain earthy salts are sure to become contaminated with lead if exposed to that metal in the presence of air; and the purer the water the greater the quantity dissolved, generally speaking. Rain-water, of course, from the absence of earthy salts, is very soft, and on that account is, for some purposes, preferable to hard waters; but it has a disagreeable taste, and, for this and other reasons, it is not the best for drinking. Rain, after it reaches the earth, soaks down into it, and during its passage through the various strata dissolves certain salts, etc., the quantity and nature of which vary, of course, with the nature of the strata with which it comes in contact. When this takes place on high ground the water percolates the strata, and very frequently finds an outlet at some lower point, as a spring. One or more of these springs is generally the source or commencement of rivers, which, as they flow on in their course, become increased in size by the various additions of water received from rain, drainage from the surface of the earth, etc. The springs above-mentioned generally yield hard waters, that is, water containing earthy salts in solution, the most frequent of which are carbonate of lime, carbonate of magnesia, sulphates of lime and magnesia, common salt, and organic matter. These are the substances which the rain, containing a considerable quantity of carbonic acid in solution, dissolves in its passage through the earth. Spring-waters resemble well-waters, and will be described more particularly further on. The river-water, receiving supplies from those other sources which do not contain earthy matters, is, of course, softer than spring-water.

River-water usually contains from 10 grains to 20 grains or 25 grains of solid matter per imperial gallon of 70,000 grains. The quantity, however, varies with the time of the year, and the dryness of the season. The average composition of the Thames water is as follows, in grains per gallon :—

		The Colne.
Carbonate of lime, ...	13·308	15·835
Carbonate of magnesia, ...	trace	trace
Sulphate of lime, ...	2·482	1·108
Chloride of sodium, ...	1·622	1·677
Organic matter, ...	3·250	1·830
	20·662	20·450

The above-mentioned substances are those most generally found in river-water, the quantities per gallon and the relative proportions of the constituents varying according to circumstances. The hardness of water is generally determined by a solution of soap in proof spirit, made of such a strength that every degree of hardness shall be equivalent to one grain of carbonate of lime in a gallon. This is known as Dr. Clark's soap test. The hardness before boiling of the Thames water above was 15·13°, and that of the Colne 16·4°. In the above and similar waters the carbonate of lime is held in solution in the water by the presence of free carbonic acid. When the water is boiled this carbonic acid escapes, and the carbonate of lime is deposited; and it is this deposit which forms the principal incrustation in kettles, steam-boilers, etc. The removal of this carbonate of lime, or the greater portion of it, of course renders the water softer than before boiling. The hardness after boiling of the Thames water above was 6·75°, and that of the Colne 6·5°. Another important ingredient in river-water which is to be used for domestic purposes is the quantity of free oxygen gas it has dissolved in it; for, as long as there is the average quantity of this gas present, putrefaction of the organic matter is not likely to take place. Although ordinary air contains four volumes of nitrogen to one volume of oxygen, that which is dissolved in water should be, owing to the superior solubility of oxygen over nitrogen, one volume of oxygen to two volumes of nitrogen. When the proportion of oxygen is less than one-third that of the nitrogen, the water must be looked upon as imperfectly aërated. Of course it is necessary that, when the quantities of these gases are to be determined, the glass bottles in which the water is collected should be perfectly filled, and have well-fitting glass stoppers; and even then the determination should take place within twenty-four or certainly forty-eight hours after the sample was collected, for the organic matter present will speedily remove a considerable quantity of the oxygen. One hundred volumes of water will dissolve three volumes of oxygen and one volume and half of nitrogen. A solution of permanganate of potassium of a certain strength is often used to determine the quantity of organic matter present in waters, but it is at the best very uncertain and unsatisfactory, and only useful as an addition to other tests.

Towns that are supplied by water companies generally use river-water; and the object of the filtration through beds of sand, etc., is to remove all suspended matter, and perhaps a little of the organic matter when the filter beds are freshly made. The only means of removing the greater quantity of the organic matter present in the water is by filtration through charcoal, animal charcoal being the best for this purpose. These waters, containing earthy salts in solution, are not so good as soft water for certain culinary purposes, and for making infusions—as tea—and for this occasion many persons add a small quantity of carbonate of soda, which increases its solvent power without injuring the water, if care be taken not to use too much. River-water, when properly filtered and comparatively free from organic matter, is generally the best for domestic and other purposes, from the fact of its not being very hard, and that the salts dissolved in it prevent the possibility of its being rendered poisonous by dissolving lead from cisterns and pipes; and for these latter reasons water, such as that from the Thames, when properly filtered, especially after filtration through charcoal, is far preferable to those which are so free from earthy salts—as the water of Loch Katrine, etc., which have frequently been put forward as standards of good waters. A good water for domestic use should contain enough carbonate and sulphate of lime in solution to prevent contamination with lead, and be as free as possible from organic matter, especially animal.

Well-Waters.—The waters from wells vary much more from each other than do river-waters, from the fact of the waters passing through a very different strata in different spots, and having no direct addition of rain-water. We may take the wells in the different strata in and around London as fair examples. In the first place, there are the wells in the gravel above the 'London clay.' The water found in these is principally or entirely surface-water, and often receives the drainage from sewers, churchyards, etc., so that the composition of the waters from these wells differs very greatly, even in short distances; some of them containing only the ordinary constituents, carbonate of lime and magnesia, and sulphates of lime and magnesia, common salt, with a moderate quantity of organic matter; while others, again, are very impure, and totally unfit for domestic use of any kind, on account of the great quantity of organic matter and nitrates produced by the oxidation of nitrogenous organic matter and salts of potassium, with the quantity of common salt greatly increased, and also frequently some ammonia, formed from the putrefaction of nitrogenous organic matter. The nitrates would arise from organic substances which had passed into the water some time previously, and had had time to become oxidized by the air dissolved in the water, whereas the ammonia would arise from more recent contamination, and very likely putrefaction still taking place. Those pumps seen in the streets of London receive their supply from these sources, and are often placed close to churchyards, from whence they receive the drainage, and hence the contamination. From the decomposition of organic matter large quantities of carbonic acid are formed, and this, being dissolved in the water, makes it sparkling and very pleasant to drink. On this account these waters are most deceitful, and in hot weather most dangerous, and were most wisely closed during the late visitation of cholera, many cases of serious illness having been at various times clearly proved to arise from drinking these waters. The following analysis will give some idea of the nature of these waters:—

Composition of Solid Matter per Imperial Gallon.

	Bishopsgate Street Within.	Fenchurch Street.
Carbonate of lime and magnesia, ...	24·70	21·00
Sulphate of lime, ...	17·00	18·30
Alkaline sulphates, ...	...	...
Alkaline chlorides, ...	17·50	14·20
Alkaline nitrate, ...	20·20	22·40
Silica, Alumina, &c., ...	1·30	0·60
Organic matter, ...	5·30	6·60
	89·00	83·10

The wells in the 'London clay' are few and unimportant, the water being frequently very bad and small in quantity. The wells in the chalk and the sand above the chalk are the next, and are the most important of all, from the large supply and the temperature of the water, which is pretty constant all the year round, and is used by brewers for cooling purposes. These wells, of which there are very many, vary from 300 ft. to 600 ft. in depth, but the water from them all is very nearly of the same composition, varying perhaps a little in different years. The most remarkable thing about these wells is the fact that, although the water comes from the chalk, there is scarcely any carbonate of lime or magnesia in it; the principal constituents being carbonate of soda, sulphate of soda, and chloride of sodium (common salt). The following analyses will show the average composition of these waters :—

Composition of the Solid Matter in Imperial Gallons.

	Grosvenor Road. Pimlico. Bamber.	Guy's Hospital. B. Odling.	Mint. Brande.	New well Bank. Warrington.
Carbonate of soda......	15·884	12·360	8·63	14·60
Sulphate of soda	15·034	15·210	13·14	13·50
Chloride of sodium ...	15·058	16·050	10·53	13·00
Carbonate of lime......	4·280	2·620	3·50	trace
Carbonate of magnesia	2·283	2·370	1·50	3·00
Silica	0·121	0·790	0·50	trace
Phosphoric acid	0·101	KSo_4 1·330	trace	KSo_4 1·01
Oxide of iron		0·050		
Organic matter.........	0·530	0·94	trace	1·60
	53·292	51·720	37·80	47·01

These waters, from the presence of carbonate of soda, and the comparative absence of earthy carbonates, are soft; on this account they are valuable for some purposes, but the proportion of salts per gallon is a drawback for others.

The waters from many of the springs in Germany and France, where there are similar geological formations, are of precisely the same nature as those in London; that is, they contain exactly the same ingredients in the same proportion to each other; the only difference being that they contain a larger quantity of the salts in a gallon of water. The only reason that can be at present given for the presence of soda salts and the small quantity of earthy carbonates is, that the water which most probably falls on the surface of the chalk at its various outcrops, percolating through it, dissolves out at first the usual constituents, carbonates of lime and magnesia, etc., as will be seen presently in speaking of the wells in the chalk at Watford, etc. These waters thus charged with earthy salts would, if they came in contact with alkaline silicates, as silicate of soda, exchange the earths for the alkali, leaving them behind as silicates, while the soda would be dissolved as carbonate, sulphate, etc., thus producing the very salts found in the water now treated of. It has been proved that some of the greenish sands, etc., above the chalk, with which this water comes in contact, do contain silicates of soda, and therefore may account for the peculiar composition of these waters. It is well known that there is one, if not two, faults in the tertiary strata about Deptford, Greenwich, and Lewisham, which causes the chalk to appear near the surface, and not having all the strata above it that it has in the regular London basin, where the soft water is found; and water taken from wells in the chalk here is hard, and more like water from the wells where the chalk outcrops. This fact would also favour the former explanation concerning the soda salts in the water from the deep wells. The following analyses of water from wells at Deptford and Greenwich will show the difference in composition:—

COMPOSITION OF SOLID MATTER IN AN IMPERIAL GALLON.

	Page's Brewery, Greenwich.	Norfolk's Brewery, Deptford.	Broadway, Deptford.
Carbonate of lime	14·926	16·850	16·340
Carbonate of magnesia	0·532	0·563	0·600
Sulphate of lime.........	4·852	3·332	3·210
Chloride of sodium.....	3·323	2·060	2·150
Organic matter	2·100	2·203	2·300
Alkaline nitrate	0·680	0·632	0·675
	26·413	25·640	25·275

The well at the Deptford pumping station became contaminated for a short time with sewage matter during the making of the large sewers in the neighbourhood, but since they have been finished it has resumed its former quality. Although the water from the chalk in London is soft, and would on that account have a greater solvent power on organic substances, such as malt, hops, etc., it will not make a bright ale, it being generally found that the hardest waters make the best ale. The water at Burton contains a large quantity of sulphate of lime, and there is no doubt that the nature of the water has a great effect on the quality of ale produced. The water from the wells in the chalk or near its outcrop contains a much larger quantity of earthy salts per gallon than river water. The following analysis of water from a well in the chalk, near the Pinner station of the London and North-western Railway, will show the composition of these waters :—

COMPOSITION OF SOLID MATTER PER GALLON.

	Grains.
Carbonate of lime, ...	12·645
Carbonate of magnesia, ...	9·206
Sulphate of lime, ...	10·306
Sulphate of magnesia, ...	...
Chloride of sodium, ...	7·219
Silica, ...	...
Organic matter, ...	1·000
	40·376

Sea water is a strong solution of salts, more especially common salt; but the water from the various seas differs in composition;

and even the same sea, as the Atlantic, appears to contain more salts per gallon, or to be a stronger solution, in the tropics than in colder regions; this may be accounted for partly by the evaporation of water which must take place in those climates. From the fact of containing so much salt in solution, its specific gravity is greater than that of fresh water, the general average being about 1·0274,—hence its increase of buoyant power.

The following analyses will show the composition of sea waters:—

COMPOSITION OF SOLID MATTER IN 1,000 PARTS OF WATER.

	English Channel. Grains.	Mediterranean. Grains.
Chloride of sodium, ...	27·060	27·220
,, potassium, ...	0·765	0·010
,, magnesium, ...	3·666	6·149
Bromide of magnesium, ...	0·029	...
Sulphate of magnesia, ...	2·296	7·020
,, lime, ...	1·406	0·150
Carbonate of lime, ...	0-033	0·200
	35·255	40·740

The analysis of the water from the English Channel is by Schwertzer, and that of the Mediterranean by Laurens. The water from the Dead Sea differs greatly from other sea waters. It contains about 25 per cent. of saline matter, and has a specific gravity of 1·211. It contains a very large quantity of chloride of magnesium and chloride of calcium, besides chloride of sodium. Ordinary sea water may be considered to contain, on the average, about 3·5 per cent. of saline matter, or about 2,500 grains per gallon. It is, on this account, unfit to drink, and of course ships are obliged to carry a supply of fresh water with them. The late Dr. Normandy, however, invented an apparatus whereby drinkable water might be distilled off from sea water, which appeared to answer the purpose well, the great object being to distil the water without letting it come in contact with the hot sides of the boiler, as is usually the case, and also to collect the gases in such a manner that they may be taken up by the distilled water; for water (as distilled) which does not contain gases is disagreeable to drink.

The effects of the several waters above mentioned on steam boilers, when used in them continually, are as follows:—

Rain water.—This water, from not containing earthy carbonates, would not form any incrustation in boilers, and the absence of salt would prevent its acting on the metals to a great extent. For stationary boilers no doubt it would answer very well for the above reasons; but, being so soft, it would be likely to boil too violently in 'locomotives,' and would prime considerably.

River water.—This water, containing carbonate of lime held in solution by the presence of free carbonic acid, boils steadily, and is not likely to prime either in stationary or locomotive boilers. As the water boils, the carbonic acid gradually escapes, the carbonate of lime at the same time being deposited in the insoluble state, and, in many instances, in a crystalline state. The slower it is deposited, the more crystalline will it generally be. In locomotives it becomes as hard as rock, and is obliged to be chipped off. This incrustation also contains some sulphate of lime; sulphate of lime being less soluble in hot than in cold water, as before mentioned. This incrustation, which becomes fastened on to the metal of the boiler so tightly, gradually eats away a portion of the metal; for, when chipped off, the incrustation will have a layer of oxide of iron on the side which has been in contact with the metal. This incrustation is a bad conductor of heat, and, when it is of any thickness, makes a great difference in the fuel required to raise steam; and on this account a dirty boiler would not raise steam as quickly as a clean one. As the water boils, and the steam is used, more water is continually added to the boiler to supply the place of that converted into steam. The carbonate and sulphate of lime being deposited during the process of boiling, the proportion of these in the water in the boiler does not increase to any extent; but the case is different with the chloride of sodium (common salt). This being so very soluble remains in solution, and is, of course, gradually increasing in the water of the boiler until it is strong enough to set up a galvanic action between the metals wherever brass or copper comes in contact with the iron, as cocks, &c. The iron is the metal attacked, and, being gradually eaten away around the brass or copper gives rise to leaks, the incrustation of carbonate and sulphate of lime having the same effect in a less degree. The accumulation of solid matter in boilers in this way is incredible to some people. Of course, blowing off the boiler removes the sediment which is not so crystalline, and which is not fastened on to the boiler, and also the salt. Many processes have been tried to prevent incrustations in boilers, but none answer completely. Chloride of ammonium was once proposed. This prevented the incrustation; but it acts so rapidly on copper and brass that it created a worse evil than the one it prevented. Carbonate of soda mixed with the water in proper quantities deposits all the lime present as carbonate in a fine powder, on account of its not having time to crystallise. As soon as the water boils, all will be deposited, and of course would be entirely removed by blowing off the boiler. In stationary boilers, this answers very well when properly attended to, but in locomotives it would not answer, it causing the water to boil violently, and thus to prime.

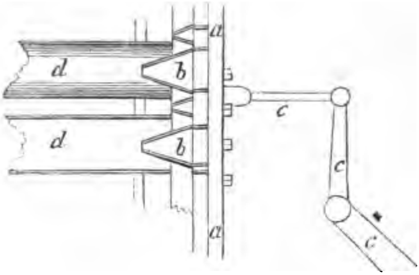
Well waters.—Those wells which yield hard water act upon boilers in exactly the same manner as river water; but, from the fact of their containing more solid matter per gallon, an equal quantity of these waters would yield a larger incrustation than river water. The water from the chalk in the London basin, which contained the soda salts, answers well for stationary boilers, if the solution of salts is not allowed to get too strong before blowing off, otherwise they would set up galvanic action. The carbonate of soda already present renders it very soft, and the small quantity of earthy carbonates is deposited as a fine powder. This water will not answer for locomotives. It boils so violently that it primes considerably, and, in ascending a hill, wholesale, so much so that the engines run short of water much sooner than they ought to, and having to keep constantly adding fresh water to the boiler to take the place of that thrown out, steam cannot be kept up properly. On this account the London and North-Western Railway Company were obliged to abandon the use of the water from their well at Camden Town. It, however, answers admirably for cleaning off the incrustation; the engines being filled with this water for a week at home and kept boiling, it loosens the incrustations which may thus be more easily removed. The London, Brighton, and South Coast Railway Company have a well at Victoria Station, but were obliged to abandon the use of that water, at least by itself. Well waters containing a quantity of soluble salts, soon become too stro and prime from this account, as well as act upon the brass and copper, so much so that boilers are almost covered in front with incrustations of salt. This was the case at Crossness when the works for the pumping station were building, water containing a considerable quantity of salt being used in them. Of course the boilers are greatly injured, and rapidly destroyed. Sea water acts in the same manner, but being so strong a solution it requires no concentration before it begins to take effect, and must be very frequently blown off."

In connection with the above, the following is a letter from the author addressed to the editor of the "Mechanics' Magazine:"—"After the discussion on my paper, read before the Society of Engineers, on March 18, on 'Water and its Effects on Steam Boilers,' I wrote an addition to the paper, and gave it to be published with the paper, but I find it has not appeared, and the manuscript has been lost. I shall feel greatly obliged by your kindly inserting this letter in your next publication. Nearly all, if not all, waters used in steam boilers may be divided into three classes. 1st, those which form incrustation in boilers, but do not contain enough permanently soluble salts (as common salt, &c.) to render them strong saline solutions in the boiler until after some considerable time. The Thames water above Kew and some well waters are of this class. 2d, those waters which form little or no incrustation, but from the fact of their containing a considerable quantity of permanently soluble salts rapidly become strong solutions in the boiler, and set up galvanic action between the brass and iron wherever they come in contact. The waters of the deep wells of the London Basin, but more especially sea water, and some waters into which sea water percolates. and the Thames at Crossness are of this kind. 3d, those waters which both form an incrustation and also rapidly become strong saline solutions in the boiler and corrode the metals. The water from some of the London pumps (Bishopsgate-street, &c., analyses of which were given in my paper), are of this kind. It follows from the above, that the injurious effects of the various waters on boilers is either the formation of an incrustation or the formation of a strong saline solution, which corrodes the metal and causes leaks, &c.; or both of these together to a greater or less extent. Before any efficient remedy can however be applied to prevent these evils (of which perhaps incrustation is the least) the composition of the water must be known, and this can only be found by an analysis of the water. The composition of the water being known, the remedy, if any, is easily found. For waters of the first class, as the Thames water above Kew, &c., where the evil to be prevented is incrustation, a little carbonate of soda, or still better caustic soda, added in solution to the water in proper quantities, will entirely prevent incrustation, and will not set up other mischief. This will be found to be much better than any other substance, patent or otherwise, but it must be done properly and in proper quantities. It will, in the long run, be less trouble than removing incrustation, and the boilers will last longer, besides the saving of fuel. The only remedy for the formation of strong saline solutions is to blow off the boiler partially or completely whenever the water is beginning to do mischief. To add soda to these waters would be to increase the mischief and do no good. The effect of a little fat being put into the boiler where very salt water (as sea water) is used is this:—Common salt is as soluble in cold as in hot water, and separates the surface as a scum or scales as the water evaporates, and causes priming. The fat, when put into the boiler, melts, and being lighter than water, floats on the surface in a thin layer, and covers the salt, preventing priming, but it does not prevent the action of the water upon the metals; and the addition of fat to a boiler is in itself highly dangerous."

SECTION SECOND.—SMOKE-CONSUMPTION, FURNACES, &C.

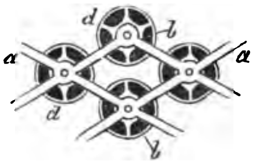
33. *New Smoke-Consuming Apparatus.*—Messrs. Roby, the well-known engineers of Lincoln, exhibited at the last show of the Smithfield Club, December, 1866, 'Lake's smoke-burning apparatus,' an invention applicable to tubular boilers. This invention can scarcely be called a novelty, inasmuch as we believe it was proposed some years ago; yet it may be claimed as one, nevertheless, as it is, at all events, now first introduced into notice. In the smoke-box end of the boiler a frame-work of metal, *a a*, fig. 57, is jointed in such a manner that, by means of a handle outside the smoke-box, it can be moved to and from the tube plates, into which the tubes of the boilers are fixed. This frame

Fig. 57.



carries a series of conical plugs, *b b*; these are not solid but fluted, so that when they are moved forward by the levers *c c*, and thereby inserted into the apertures of the tubes, spaces—shown in black at one of the tubes in fig. 58—are left, through which the heated air and gases can escape to the chimney. It is right to state that many engineers do not conceive the action of this apparatus to be likely to be beneficial—anything, indeed, but that; at the same time, it is right to state that Messrs. Roby have carried out a series of most elaborate experiments with an engine to which the apparatus has been attached, and they report two very remarkable results. The first of these is, that the interior of the tubes is kept free from all deposited matter, and this so effectually that at the end of a month they were as clean as when the boiler was first set to work. Secondly, and the most important, a saving of fuel equal to 23 per cent. This, of course, is the result of the freedom of the interior of the tubes from soot, &c.—a general and a prolific loss in tubular boilers where coal is consumed. But how the tubes are kept clean by means of an

Fig. 58.



apparatus which some engineers hold should have an opposite effect, remains yet to be explained. We know of more than one paradox in engineering: perhaps this comes to be added to the list. Meanwhile, the invention is in the hands of energetic men who know what they are about, and are not likely—to use a forcible, if not an elegant, expression—'to take the wrong bull by the horns.'

34. *Smokeless Furnace.*—"The Fuel-Saving Furnace Company of New York are manufacturing a furnace for consuming bituminous coal so that no smoke will be produced. The bars are inclined at the sides (all the bars run crosswise), at such an angle that the coal supplied from the roof descends by its own gravity to the centre of the grate, which is flat, with an inclination to the rear. The fuel-chambers situated in the roof, automatically feed the furnace, and are practically air-tight. This arrangement prevents an influx of cold air and the escape of unconsumed gases forced through the chimney by the cold draughts. The supply of the heated air is admirably arranged. An air-flue passes round the arch, and distributes through interstices of the brick-work, raised to a white heat, air, which mingling with the gases produced immediate combustion. The arch of the roof is of considerable assistance in accomplishing this, as it reflects the heat of the fire. Very little thought will convince our readers of the numerous advantages resulting from these improvements. The constant supply of the fuel, the prevention of all cold draughts, and of the escape of fumes and gases, the reflection of the heat by the arch, the admission of a continuous supply of highly heated air, all contribute to consume the smoke and other substances wasted in the ordinary furnace, accomplishing thereby, in addition to other advantages, a large saving of fuel. A modification of this arrangement is applicable to the burning of anthracite, sawdust, peat, and other materials."—*English Mechanic.*

35. *The Consumption of Smoke in the Potteries.*—"The rapid approach of the time when the smoke consumption clauses of the Sanitary Act, 1866, will come into operation is a subject which creates considerable solicitude in the Staffordshire Potteries, where it is the popular impression that the enforcement of the Act will be fraught, on account of the expense involved, with disastrous consequences to the trade. A timely discovery has, however, bee

made, the application of which will not only go far towards relieving the potters from the penalties consequent on non-compliance with the clauses in question, but will at the same time enable them to effect a material saving in the consumption of coal. The new process was first introduced to the trade by Messrs. Holdcroft and Wood, of Tunstall, and it is now in successful operation, not only at their works, but also in several other manufactories in Hanley and other places. The new plan may be thus described. The fires being lighted, and baited in the usual way, the heat and smoke are carried partly into the outer circumference of the inside of the oven, and partly by reverberating tunnels laid under the floor of the oven to a central hole, and in the ordinary way, both heat and smoke, after passing through the oven, escapes into the open air. The new process, however, prevents not absolutely but in a surprising degree, both nuisance and waste. The aperture at the top of the oven (not that at the top of the hovel or outer casing of the oven) is fitted with a damper, which is left open in the earliest period of the firing, but as combustion goes on it is gradually lowered by stages of about 4 in. each, and both smoke and heat are consequently to a great extent prevented from escaping. They are not, however, confined within the oven, but by a downward draught are carried through the oven again—the smoke being mostly consumed in the process—and passing into the central hole are conveyed along an underground flue to a small chimney, which creates the draught by which the reverberation of the smoke and heat from the top of the oven is carried on. The contrivance of the damper and the flue communicating with the tall chimney are the leading features of the new process. The saving of coal per oven is from four to six tons, and the greater steadiness in the firing reduces by one-third the loss in 'saggars,' the large coarse vessels in which the ware is placed to be fired. The first expense is small in comparison with the saving ultimately effected, for one tall chimney is sufficient to create the required draught for any number of ovens."—*Engineer.*

36. *The Mechanical Equivalent of Heat.*—"Our present mechanical equivalent of heat is established by proofs of such seeming strength and conclusiveness that it is no light matter to call its truth in question; however, I propose to show that these

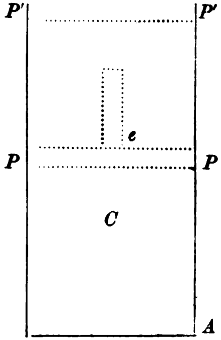
proofs are not really so conclusive as they appear, and that our equivalent, which says a unit of heat will give 772 foot lbs. of force, has no direct proof for its support, but the all direct proof which can at the present time be brought to bear on the subject would go to establish quite a different measure for the power of heat. I will first quote from 'Heat Considered as a Mode of Motion,' by Professor Tyndall, to show how the equivalent has been established, and will then present the reasons for making the above statement.

'Using the accurate numbers, the quantity of heat applied when the volume is constant, is to the quantity applied when the pressure is constant, in the proportion of 1 to 1·421.

'This extremely important fact constitutes the basis from which the mechanical equivalent of heat was first calculated. And here we have reached a point which is worthy of, and which will demand your entire attention. I will endeavour to make this calculation before you.

'Let C, (in fig. 59,) be a cylindrical vessel with a base one square foot in area. Let P, P, mark the upper surface of a cubic foot of air at a temperature of 32° Fah. The height A P will then be one foot. Let the air be heated till this volume is doubled; to effect this it must, as before explained, be raised 490° Fah. in temperature; and when expanded, its upper surface will stand at P′ P′, one foot above its initial position. But in rising from P P to P′ P′ it has forced back the atmosphere, which exerts a pressure of 15 lbs. on every square inch of its upper surface; in other words, it has lifted a weight of 144 × 15 = 2,160 lbs. to a height of one foot.

Fig. 59.



'The "capacity" for heat of the air thus expanding is 0·24 water being unity. The weight of our cubic foot of air is 1·29 ounces, hence the quantity of heat required to raise 1·29 ounces of air 490° Fah., would raise a little less than one-fourth of that weight of water 490°. The exact quantity of water equivalent to our 1·29 oz. of air is 1·29 × 0·24 = 0·31 oz.

'But 0·31 oz. of water, heated to 490° is equal to 152 oz., or

9½ lbs. heated 1°. Thus the heat imparted to our cubic foot of air, in order to double its volume and enable it to lift a weight of 2,160 lbs. one foot high, would be competent to raise 9½ lbs. of water 1° in temperature.

'The air has here been heated under a constant pressure, and we have learned, that the quantity of heat necessary to raise the temperature of a gas under constant pressure a certain number of degrees, is to that required to raise the gas to the same temperature when its volume is kept constant, in the proportion of 1·42 : 1, hence we have the statement—

$$1{\cdot}42 : 1 = \overset{\text{Lbs.}}{9{\cdot}5} \; ; \; \overset{\text{Lbs.}}{6{\cdot}7}$$

which shows that the quantity of heat necessary to augment the temperature of our cubic foot of air, at constant volume, 490°, would heat 6·7 lbs. of water 1°.

'Deducting 6·7 lbs. from 9·5 lbs., we find that the excess of heat imparted to the air in the case where it is permitted to expand, is competent to raise 2·8 lbs. of water 1° in temperature.

'As explained already, this excess is employed to lift the weight of 2,160 lbs. one foot high. Dividing 2,160 by 2·8, we find that a quantity of heat sufficient to raise one pound of water 1° Fah. in temperature, is competent to raise a weight of 771·4 lbs. a foot high.

'This method of calculating the mechanical equivalent of heat was followed by Dr. Mayer, a physician in Heilbron, Germany, in the spring of 1842.

'In August 21, 1843, Mr. Joule communicated a paper to the British Association, then meeting at Cork, and in the third part of this paper he describes a series of experiments on magneto-electricity, executed with a view to determine the "mechanical value of heat." The results of this elaborate investigation gave the following weights raised one foot high, as equivalents to the warming of 1 lb. of water 1° Fah.

1.	896 lbs.	5.	1026 lbs.
2.	1001 lbs.	6.	587 lbs.
3.	1040 lbs.	7.	742 lbs.
4.	910 lbs.	8.	860 lbs.

'In 1844 Mr. Joule deduced from experiments on the condensation of air the following equivalents to 1 lb. of water heated 1° Fah.

823 foot lbs.
795 foot lbs.
820 foot lbs.
814 foot lbs.
760 foot lbs.

'As the experience of the experimenter increased, we find that the coincidence of his results becomes closer. In 1845, Mr. Joule deduced from experiments with water, agitated by a paddle wheel, an equivalent of

890 foot lbs.

'Running up his results in 1845, and taking the mean, he found the equivalent to be

817 foot lbs.

'In 1847, he found the mean of two experiments to give as an equivalent

781·8 foot lbs.

'Finally, in 1849, applying all the precautions suggested by seven years' experience, he obtained the following numbers for the mechanical equivalent of heat:—

772·692, from friction of water, mean of 40 experiments.
774·083, from friction of mercury, mean of 50 experiments.
774·987, from friction of cast-iron, mean of 20 experiments.

'For reasons assigned in his paper, Mr. Joule fixes the exact equivalent of heat at

772 foot lbs.

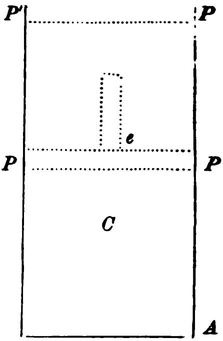
'According to the method pursued by Mayer, in 1842, the mechanical equivalent of heat is

771·4 foot lbs.

'Such a coincidence relieves the mind of every shade of uncertainty, regarding the correctness of our present mechanical equivalent of heat.

Having produced the proofs by which our present mechanical equivalent of heat has been established, I now ask, is this experimental proposition of Dr. Mayer's a correct one; do the 2·8 units of heat really give so much force as 2,160 foot pounds? They do not; there is a deception in so calculating the amount of work performed.

Fig. 60.

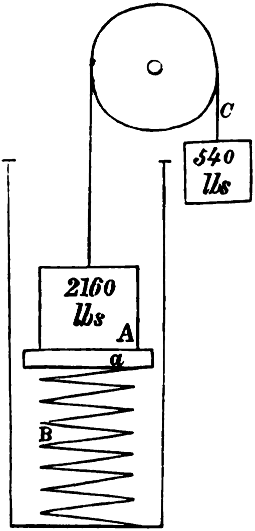


In order to prove this, and find what the amount of work performed really is, suppose the piston, *e*, fig. 60, is elevated by the application of outside force, and without applying heat; then the force necessary to raise the piston, *e*, one foot, from P to P′, will be 540 foot pounds, and not 2,160 foot pounds. If there was a perfect vacuum below the piston, or if the cubic foot of fluid below the piston were non-elastic like water, then the amount of force necessary to lift the piston from P to P′, would be 2,160 foot pounds, but as it is, there is no such vacuum, and the static repulsiveness of the air below the piston greatly assists to overcome the resistance of the atmosphere on the upper side of the piston. When the piston has been raised one foot by outside force, then the vacuum in C is 7·5 pounds to the square inch, and shows that there has been an average resistance of 3·25 pounds to the square inch, through the space of one foot, which gives 540 foot pounds as the force necessary to elevate the piston one foot from P to P′. This 540 foot pounds being all the work there is to be done in the case, it is clear that the 2·8 units of heat have performed only this amount of work.

To vary the proposition, suppose after the piston has been raised one foot to P′ by heat, that all the experimental heat were then extracted from the air in the cylinder, we should then have a vacuum of 7·5 pound, which would give an average vacuum of 3·25 pounds, to force the piston down through the space of one foot; and the amount of work done in such condensation stroke would be 540 foot pounds, and would be an exact return of the force lost in overcoming the resistance of the atmosphere during the expansive stroke.

I do not wish to multiply words unnecessarily, but think that a mechanical comparison will make this point more clear. A, fig. 61, is a weight of 2,160 lbs., and represents the pressure of the atmosphere on the upper side of the piston or platform, *a*; below the piston is a very elastic spiral spring, B. The weight, A, is placed on the platform, and compresses the spring until the weight, A, is wholly sustained by the compressed tension of the spring, B. Now suppose a second weight, C, of 540 lbs. is suspended over a pulley so that its weight may exert a lifting force of 540 pounds on A; then if the spring has a flexibility in keeping with the elasticity of the cubic foot of air, in the previous experiment, the weight, A, will be raised by C, through a space of one foot, the spring, B, which has been compressed by 2,160 pounds of pressure, greatly assisting in the operation of lifting A. The weight, C, in this case, causes the weight, A, to be raised one foot, but still there has been but 540 foot pounds of energy brought to bear, and this is all the work that has been done, and is all that can be recovered by removing C. It is useless to pursue this point further, it is fatal to the exposition of Dr. Mayer, and all the force of Dr. Mayer's experiment is changed in another direction. It now goes to establish a mechanical equivalent of heat at 193 foot pounds of force for a unit of heat, instead of 772 foot pounds, as before.

Fig. 61.



Now, with relation to Dr. Joule's experiments, it will be observed that all of them are conversions of mechanical power into heat, and not in a single instance has he converted heat into a mechanical equivalent. It will also be observed that Dr. Mayer's method stood alone as the only instance where heat was converted into force, and that instance has now taken a new form, which is in direct conflict with Dr. Joule's conversions of force into heat. Here is a direct issue between the opposite conversions, and who can say what the ultimate result is to be? How are we to know that heat and force are convertible, back and forth in even measure? We have no proof that it is so, while, on the other hand, we have strong proof that it is not so. Dr. Joule's experiments show that 772 foot pounds of force may be converted into one unit of heat; while, on the other hand, Dr. Mayer's experiment, when rightly considered, shows that one unit of heat may be converted into 193 foot pounds of force. One is the heat equivalent of mechanics, and the other the mechanical equivalent of heat.

How are we to know that there are not some collateral causes (or diversions) which prevent the consummation of even conversions? We do know that by our best endeavours we have never yet succeeded in making such conversions. There is an important link missing in Dr. Joule's evidence bearing on the establishment of the mechanical equivalent of heat, and as things now stand it falls upon him to show that these conversions can be made in full measure, before his experiments have any direct bearing on the question: as they stand they are nothing more than a side issue.

It is reasonable to suppose that such even conversions should be made; but such supposition has no force without proof to sustain it, and while there are strong proofs to the contrary. The corrected experiment of Dr. Mayer does not now stand alone, to establish the mechanical equivalent of heat at 193 foot pounds of force, for a unit of heat. If air is confined and heated under constant volume, and then allowed to expand and do its work, it gives 193 foot pounds of work for each unit of all the heat employed. And again, if water is confined so that steam is generated (under the most favourable circumstances possible) at a density of water, or under a pressure of 25·497 pounds to the square inch, then water gives 193 foot pounds of work (190·3 foot pounds by my calculation) as a return for each unit of all the heat employed; and thus gives in its allegiance, and lifts up its voice for a new 'equivalent.'

It may be, eventually, when further developments have been made, that 772 foot pounds will prove a correct measure of force which can be developed from a unit of heat; however, it will be time enough to set up a better standard when we find it."—Mr. F. A. Morley, in the *Scientific American.*

◆

DIVISION THIRD.

STEAM ENGINES.

SECTION FIRST.—STATIONARY ENGINES.

37. *Steam Engines at the Paris Exhibition of* 1867.—The class of engines treated of under the present section was illustrated with so many examples, that the space at our disposal will by no means suffice for us to glance at anything like the whole of them; we must content ourselves, therefore, by inserting here notices of such forms as will be likely to prove most interesting to our readers, either from their novelty or suggestiveness in arrangement and construction. The first we notice was certainly the novel feature of this department, namely (*a*), *Hick's Engine*, which was exhibited in the American Department, and of which, in Plate VII., we give in fig. 1 a drawing showing the general arrangement, in which *b b b b* are four single-acting cylinders placed opposite to each other, the piston-rods of the moveable pistons of which are directly connected to the shaft of the fly-wheel, these are the only moveable parts of the engine, and, being all boxed-up, form an exceedingly compact arrangement. The pistons are so constructed as to act in the capacity of the ordinary slide-valve, the parts being in connection and combination with parts in the cylinders; so that all the complicated mechanism of slide-valves, eccentrics, levers, etc., etc., of an ordinary engine are dispensed with, and the whole of the moving parts reduced to a minimum. Each piston acts as a slide-valve to the cylinder immediately contiguous; and it is also capable of being so adjusted that it cuts off its own supply of steam at any desired point, thus enabling the engine to work on the expansive principle. By arranging also for each piston to take its own supply of steam before the next one has finished its stroke, a perfectly uniform motion is produced, the dead points being passed over easily. The engine runs at very high speed, and is in every way worthy of special notice. Fig. 62 represents the pistons, crank, shaft pulley or fly-wheel; F, governor pulley; E, disconnected

box in the same position occupied in the engine when the whole are put together. The pistons show the ports and passages for steam and exhaust. A form in which this engine is used is the vertical, the four cylinders being placed at right angles to each other; this is illustrated in fig. 63.

Fig. 62.

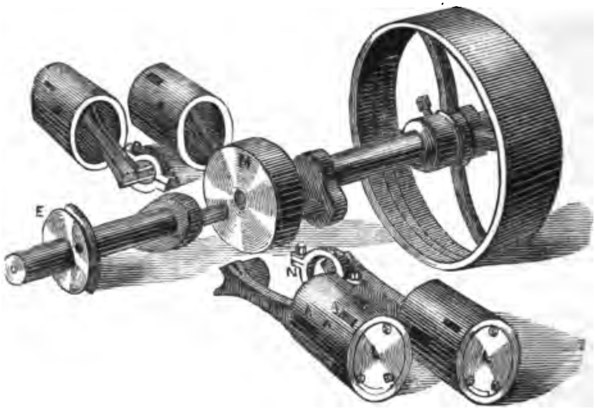
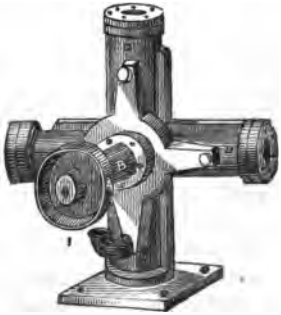
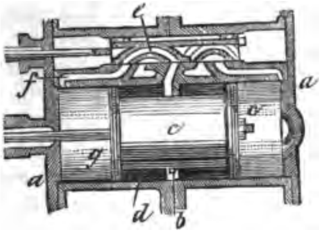


Fig. 63.



(*b*) *The Allan-Porter Engine.*—This engine—which has for its aim the working at a very high speed, so as to save weight, space, and cost, by working a small engine quickly rather than a large one slowly—attracted very great attention in the Exhibition. The following diagram, fig. 64, will explain the arrangement as originally introduced by Mr. Allan:—The

Fig. 64.



cylinder *a a* is made of length equal to twice the length of stroke. It is divided exactly in the centre of its length by a division *b*, or rather annular ring, the inner periphery of which is packed after the fashion of metallic pistons with spring packing, with this difference that the packing presses inwards in place of outwards. The packing of this division presses upon the surface of a trunk *c*, which is provided with light covers or pistons. The whole part *c c'*, may be called the piston of the engine, and to which the piston-rod is attached. On commencing to work the engine, the steam is admitted by one of the ports to the annular space *d*, and pressing upon the end of the annular ring or piston *c*, forces the piston along the cylinder. On the completion of the stroke, the port *e* is opened, and the steam, escaping from the space *d*, passes along *e f*, and gains admission to the space *g*, into which it fully expands, and presses the piston *c* in the contrary direction. The steam, it will be seen, is used twice over in the same cylinder, and fully expanded, and this without using any separate expansion-valve, or necessitating the employment of a second eccentric. The full pressure of the steam acts upon the decreased area of the annular ring towards inside of the annular space *d*, while the expended steam acts upon the increased area of the piston *c* in its full extent towards the side *g*.—It is difficult to see upon what principle the engine exhibited called the "Allan Engine," for, save the general principle aimed at by Mr. Allan, the working at a high speed, the engine exhibited owes its introduction almost entirely to Mr. Porter—as will be seen by the following article from the "Scientific American" of July 13th, 1867:—"The distinctive feature which gives it its name is the arrangement of the valve gear for advantageous expansive working, the invention of a well-known New York machinist of that name. Mr. Chas. T. Porter, who has undertaken to introduce it to England, has however combined in the engine a number of qualities which together tend to make a machine of unusual excellence. The first object that has been sought has been to produce an engine adapted to a high speed, and as the valve gear is a positive and not a detaching one, it is particularly suited for this purpose. The advantages of high speed theoretically considered are quite obvious, since weight, space, and cost, are all saved by setting a small engine working rapidly to do the work of a large one moving slowly. The difficulty however has been to produce an engine in which it was possible to maintain a high speed without a destructive wear and tear of the parts. A high speed engine must have no rattle traps about it, must have ample bearings and wearing surfaces, and all its adjustments must be such as to have no slack, though without the introduction of any superfluous keys or adjusting pieces which may either work loose or put it in the engineer's power to spoil his engine. These points and others which will appear as we proceed have been kept carefully in mind in the design of this engine. First, in reference to the valve gear. It is well known by all familiar with the subject, that the use of a single slide valve to accomplish the admission, suppression and release of the steam to and from the cylinder is only possible when we are willing to sacrifice something of the peculiar characteristics which we should wish each of these elements of the distribution to have. In all engines therefore in which a correct distribution is sought, the attempt to make a single valve accomplish so many different functions is abandoned, and in most cases, as in the Corliss, Sickles and other arrangements, four separate valves are set to admit and release the steam. This is the plan also which is adopted in the Allan engine, although, as both exhaust valves are worked by a single stem, we might perhaps regard them as but a single valve in effect. A single eccentric motives all the valves, but the motion imparted to them is modified by interposing between each steam valve, eccentric rod and its valve stem, a bell crank rock shaft. The cut-off is varied by the governor raising or lowering the ends of the rods which we have called the eccentric rods, in a curved slot or link formed in the eccentric strap itself, and in order that each steam valve may have exactly the motion required for its own functions, these rods, though starting from the same block, are made separate and of different lengths. This enables the following condition, which is the gist of the whole, to be obtained. Each bell-crank rock shaft is so placed that when the eccentric is at its full throw in the direction of opening its valve, the arm towards the eccentric is nearly on its centre, or in line with the eccentric rod, while the arm connected to the valve stem is nearly vertical, or at right angles to the rod. By this means, it will be seen, a very slight motion of the eccentric produces a very rapid motion of the valve, while, when the eccentric is at the other extremity of its throw, the relative position of the arms of the bell crank being reversed, a very considerable movement of the eccentric produces but little motion in the valve. In other words, it remains nearly at rest when closed until the time comes for it to admit the steam, when it rapidly opens a wide port and as rapidly closes it again. The exhaust valve receives a constant motion from the end of the link. The steam valves are placed in a separate chamber from the exhaust, the latter being situated beneath the former. There is a rather large amount of port space involved in this arrangement, but every care is taken to reduce it to a minimum. Equilibrium valves are used for the admission, constructed on a very simple and beautiful principle. The valve is a rectangular frame, like the four sides of a box without top or bottom. Over the back of this is a fixed plate which receives the pressure of the steam and under which the valve just freely slides. This plate is recessed on its under side, and its edges and those of the valve and seat are so situated that when the valve begins to uncover the port it also opens an equal space at each of its sides, top and bottom, thus giving in effect a port four times the length of the valve. The exhaust valve is also constructed so as to open twice its own length of port. The engine at work in the Exposition is running at 200 revolutions per minute, and the diagrams taken from it show a quick and free admission of the steam, giving an initial pressure but little below that in the steam chest (to which an indicator is also applied); a sharp cut-off, an early release, and complete escape of the steam before the returning piston, leaving but half a pound difference of pressure between the cylinder and condenser as measured by the same indicator, and lastly a small amount of compression just sufficient to ease the motion of the reciprocating parts.

The condenser is a part of the engine on which considerable thought has been bestowed. The condensing chamber and hot well, which are side by side, form the upper part of a square casting of which the lower portion is a water chamber forming the air pump. Into this works horizontally a pointed plunger keyed to a prolongation of the piston rod, which by its displacement draws in and forces out a certain quantity of water at each alternate stroke of the piston. The movement of the water produced by this means is as gentle as could be wished at this speed, since it only rises one inch at each stroke and escapes freely at the delivery valves in the bottom of the hot well. The foot valves of the condenser are on the same level as the delivery valves, and open downwards, so that the air entering the air-pump chamber from the condenser remains on the surface of the water and is the first to pass out at the delivery valves, the top of the chamber being slightly inclined to facilitate its escape. This is a very important point, and the truth of it is to be found in the fact that the vacuum obtained remains constantly at 27¼ inches to 27½ inches. To particularize all the points in which the mechanical construction of the engine has been adapted to high speed, would occupy too much of your space. But so carefully has this been done that many who at the first glance exclaimed that such a speed was necessarily too much for any engine, have, after a more careful examination of it, confessed that the conclusion was irresistible that an engine could be designed as suitable for that as for a lower speed. In every part the designer has studied to have as few loose pieces as possible. Thus his piston is shrunk on to the rod and held firmly by that means alone. In the smaller sizes the packing consists merely of small grooves turned in the face of the piston, the action of which in preventing the flow of gases is well understood. In the larger engines Ramsbottom's rings are employed, which render all springs or other means of adjustment unnecessary. The crank-pin brass in the connecting rod is held in the solid end of the latter, in which is a wedge of a large bevel, and held by a single good bolt at the top of the rod, and another at the bottom, by means of which it can be set and firmly held at any position, the two bolts locking each other through the intervention of the wedge acting as a deep nut. Great care has also been used in the design of the crosshead to secure lightness, strength, and ample and hard surfaces. The pin is surrounded by a bush of hardened steel, with a square formed on its ends by means of which it is let into the body of the crosshead and prevented from turning. The thorough lubrication of all the parts is another vital point, and has been amply provided for, constant lubrication being in all cases adopted; in the cylinder and valve chest by Ramsbottom's 'displacement lubricator' and in other parts by suitable oil cups and wicks. The economy of oil by such means in proportion to the useful effect produced, is sufficiently evident to secure more general attention to its use. I have given this full description of this engine because it unites in itself more features of correct engineering than any other in the Exposition, and moreover being entirely American in design, though English in construction, it is something in which we may take some pride, the more so as the contents of the space allotted to us are not quite such as we should like to have had here to represent the skill of our inventors and machinists."

(*c*) *Andrews' Oscillating Engine.*—In fig. 7, Plate VIII., we give a longitudinal section of this, and in the accompanying cut,

Fig. 65.

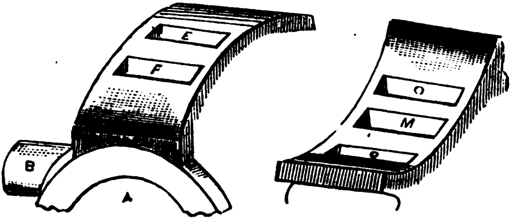


fig. 65, a perspective view of part of the valve and trunnion. "The cylinder A has two trunnions B B, working in two bearing-boxes C C (one only of each being shown) and has a projection D (shown in section) cast upon its lower side, extending the full length of the cylinder in the form of a segment of a circle, having its centre in common with trunnion B, and extending across the cylinder somewhat less than its diameter, but of sufficient width to allow of passages E and F through it of a proper size for the admission and exit of steam, and a sufficient surface in addition upon its convex face to prevent the escape of steam between it and the concave face of the steam-chest G (also shown in section), with which it forms a moveable steam-tight joint. The steam-chest G is of the same width as the projection D upon the cylinder, but somewhat longer, and has its concave face accurately turned and fitted to the convex face of D. The steam-chest G is rigidly secured in the frame H by the screw-bolts I I passing through it, and by two set-screws J J (one only being shown) under each end. It has two chambers in it, the inner one, K, for live steam, supplied to it through pipe L, and having an opening from it at M through the face of the steam-chest; the outer one, N, is for the exhaust steam, and has two openings from it through the face of the steam-chest at O O′, and has the exhaust-pipe attached to it at P. To enable the face of the cylinder to oscillate in contact with the face of the steam-chest without wear or friction and still keep the joint steam-tight, it is arranged as follows:—The trunnions B, and their bearing-boxes C, are enclosed in the trunnion-boxes Q, which have moveable caps R, for convenience of fitting-up, and set-screws S S′ in their sides, bottoms, and tops. One trunnion only, with its box, &c., is shown, and that one has its end removed to show the internal arrangement. By means of the set-screws S S′ S″ S‴ the cylinder is adjusted in its proper position relative to the steam-chest G. The inner ends of the set-screws are inserted into loose plates T T′ T″ T‴, which admit a sliding motion of the bearing-boxes C for adjustment. Between the top plates T and the bearing-boxes are inserted corrugated brass springs U. When all is in place, steam of very low pressure is admitted into chamber K, and the top-screws S are turned down until the tension of the springs U is sufficient to overcome the pressure and prevent the escape of steam between the faces of D and G. The bottom set-screws S''' are now turned up until their loose plates T''' are brought snugly into contact with the bearing-boxes C, in which position they are secured by their jam-nuts. These bottom set-screws prevent the two faces being forced together by any power applied upon the trunnions. Steam, of the full pressure that the engine is required to work under, is now admitted into chamber K, and the top-screws S are turned down until the tension of the springs U is just sufficient to counteract its pressure and prevent its escape between the cylinder and chest. The adjustment is now completed, and the expansion and contraction of the metal is perfectly counterbalanced by the varying pressures of steam, and the joint remains perfectly steam-tight with high or low steam. The action of the engine is as follows: steam being admitted into chamber K of the steam-chest, and the crank-pin V being turned down past the centre, it will be seen that the oscillation of the cylinder will bring the passage E in communication with the opening M in the steam-chest, and admit steam to the cylinder between its forward head W and the piston X, forcing the piston to the back end of the cylinder, and bringing the crank-pin to its back dead centre, and the cylinder again to the position shown in the engraving. The momentum of the balance-wheel Y then carries the crank-pin *upwards* past the centre, and causes the cylinder to oscillate in the opposite direction, bringing the passage F in communication with the opening M, and admitting steam to the cylinder between the back head and the piston, forcing the piston forward again to the position shown in the engraving, and completing a revolution. While the passage E is in communication with the steam-opening M, admitting steam to the front end of the cylinder, the passage F is in communication with the back opening O′ of the exhaust-chamber, allowing the exhaust steam to escape freely from behind the piston. When passage F is in communication with the steam-opening M, admitting steam to the back end of the cylinder, the passage E is in communication with the front opening O of the exhaust-chamber, allowing the exhaust steam to escape freely from the front side of the piston. Should the engine be required to run in the opposite direction, it is only necessary to transpose the steam and exhaust-pipes, making the outer the steam and the inner the exhaust chamber. When engines require to be reversed while running, we apply a reversing-valve, which instantaneously reverses the steam and exhaust, and by the use of which our double engines, which are connected to one crank at right angles to each other—having no dead point—can be reversed in one second, when running 200 revolutions per minute under a full head of steam."

(*d*) *Thomson's Rotatory Engine.*—In figs. 2 and 3, Plate VII., we give drawings illustrative of this form of engine which is attracting considerable attention amongst practical men, and of which the following is a description as given in the "Engineer" of May 31st, 1867:

"As will be seen from our illustrations, the axis round which the piston or pistons in Mr. Thomson's engine revolve is coincident with the axis of his cylinder. The steam and exhaust ports in each semi-circumference of the cylinder are spaced at a distance of 67½ deg. from each other, and, as will be observed, the distance between the packing strips of each contiguous pair of pistons is 90°.

Assuming the packing strips of one of the pistons to have just passed the steam ports (which though, as we have said, 67½ deg. distant from their respective exhaust ports, are exactly opposite, or 180 deg. distant from each other), the steam entering behind the piston which is just passing it, and in front of the other piston which has not yet reached it, but has passed the exhaust port, acts like a wedge, with a tendency to drive with equal force one piston forward and the other back; and so it would, and this would be the only result of admitting the steam, but for the differential gearing which Mr. Thomson intervenes between the axes of his pistons as they issue from the cylinder and the fly-wheel shaft of the engine. By reference to the accompanying engravings it will be seen that when one of the pistons has just passed the steam port, its corresponding elliptical wheel is driving with its shorter radius on to the longer radius of the wheel on the working shaft on to which it gears, whereas the piston immediately following it, and which has passed the exhaust port at the moment the other passed the steam port, is working under exactly opposite conditions, viz., with its longer radius operating on the shorter radius of the geared wheel on the driving shaft.

The result is that the first piston is driving the fly-wheel shaft with the power of the steam on its surface multiplied by the intervening gearing, and the second piston is retarding it by a similar aggregate force, but diminished by the intervening gearing. The moment this second piston passes the steam port it begins to act, as we have described in the case of the first one, the conditions of the two pistons becoming reversed in fact, and so the action proceeds. In the foregoing we have spoken only of two pistons, but, as will be observed, each pair of the four pistons delineated are connected together, and in fact counterparts of one another, so that the movements we have described are in reality taking place simultaneously at each side of the cylinder, there being also two steam and exhaust ports in it. It might easily be imagined that there was a positive loss of the power exerted backwards on that piston which for the time is following the driving one. No steam is expended, the piston being simply dragged forward against the pressure for the time being in the boiler. The engine exhibited is not arranged for working expansively; but, as will easily be seen by any one who is disposed to give the subject a closer examination than time and space will admit of here, the valves and ports could be so arranged that any fraction of a cylinder full of steam shall be used during each revolution. In this case, however, the engine could only work one way, and Mr. Thomson states that his only reason for not exemplifying the important principle of expansion in this engine was that he considered it more important for the purposes to which it is now applied to show the facility with which it is capable of being reversed.

We may now enumerate some of those which appear to us advantageous, or which, on the contrary, still manifest difficulties thus far inherent in the rotary system. For the first the axis of revolution of the piston coincides with the axis of the cylinder, and the difficulty of making the circumferential packing tight is less than in those single cylinder rotarys, the axis of whose piston is placed eccentrically. This advantage, it is true, can also be obtained by using two cylinders, as in the case of both the other engines in the Exhibition. This, however, at once leads us into multiplication of parts. On the other hand, however, there exists to a certain extent in this engine the difficulty of obviating the unequal wear of the ends of the cylinders under the friction of the packing strips, which has been advanced against other rotary engines. The intervention also of different gearing involves the necessity of extraordinary care in the shaping of the teeth of the wheels, which must, to work true, have each the proper form to which their position on the wheel, and the consequent radius of their motion, entitles them. We must, however, remember that we are now speaking of an engine speeded up to 400 revolutions a minute, and that reciprocating engines in practice make no approach to such a speed without a greater jar than that produced by any gearing. For the purpose to which Mr. Thomson's engine has so far been applied—that of deck cranes, etc.—this power of running at high speeds without thumping has been found of considerable advantage. The vertical cylinder deck winch engine is very apt to make a ship's deck leaky if allowed to run away with light weights, and we can quite understand the rotary having an advantage in this respect.

It only remains to add that the design can lay no claim to novelty except as regards the working out of certain details. The principle of employing one piston to act as an abutment for the other was first proposed by Hornblower many years ago. He used two pistons following one another round in a circular channel, but instead of combining their action by the use of elliptical wheels, he employed a rachet arrangement, by which each piston, after making nearly a revolution, was held fast until its fellow, which was previously before it, came up behind and nearly overtook it, when the first piston was set free and the second held, and so on. We fear that Mr. Thomson's claim, if he puts one forward, to be considered the original inventor of the application of elliptical wheels to a Hornblower engine is also unsound. In 'The Engineer,' vol. xiii. page 366, will be found a letter from a correspondent describing the arrangement, which would almost apply, word for word, to Mr. Thomson's engine as it stands."

(*e*) *Special Features of French Engines.*—The following is from a paper in "Engineering," May 17th, 1867 :—"There are various specialities discernible by the engineering eye in the engines shown by French makers in the Paris Exhibition, some of which present features of advantage, and others the reverse. But where these engines differ from ordinary English types, it will be proper to note and analyse the difference, in order that we may the better indicate what the peculiarities of construction are, which we may. with propriety, imitate, and what those are which we may, with still greater propriety, avoid.

And, first, we may mention that a good number of the engines shown in the French department have been constructed by Englishmen settled in France, and, as a general rule, those engines are, upon the whole, the best which are the closest imitations of approved English examples. Among the engines more properly French, the most prominent speciality is the almost universal use of a separate expansive valve—generally a slide-valve on the back of the ordinary one—and this expansion-valve is sometimes adjusted by hand to alter the rate of the expansion, and sometimes by the governor. A considerable amount of complication in the apparatus is produced by this addition, especially where the rate of expansion is varied by the governor. The high price of coal in France renders economy of fuel an object of primary importance in steam engines, and hence the use of expansive working as the best recognised mode of producing economy is almost universal. But whereas in English engines this result is attained pretty completely by giving a suitable adjustment to the ordinary distributing slide, in France it is achieved only by the aid of a separate expansion apparatus, which in some cases is very complicated. We are not aware that a greater dynamic efficiency has been obtained from coal in French engines than in English ones. Even in practical working for long periods of time, and under circumstances conducive to waste, we frequently expend only 2½ lb. of coal per indicated horse power per hour, while in isolated experiments we expend only 2 lb., and even less than that. In many cases this is done without any special expansive apparatus, and with such apparatus the French engines do not exhibit greater economy. We do not, however, object to expansion apparatus in the case of large engines. On the contrary, we consider it an advantage. But it should in all cases be simple and smooth in its action, and in the case of small engines it is best dispensed with altogether. The best species of expansion apparatus applied to the French engines is that in which an eccentric moves a combination of two plates or blocks, which work over two passages on the back of the ordinary valve, through which passages the steam enters the cylinder. This arrangement, which, as we have stated elsewhere, was first patented by Mr. Bourne in 1838, and subsequently adopted by Mayer and others, has this special advantage, that it is a solid and smoothly working apparatus, which may be introduced into engines of any size. In the expansion apparatus employed by MM. Farcot and some other makers, the expansion valve is moved by tappets on the main valve, and even in small engines it makes a noise as if something were adrift in the valve-casing. This species of valve is objectionable for engines of any size, but especially so in the case of engines of large size, where the shock and noise would necessarily be very great. In all engines, whether large or small, economy of fuel is highly important, and expansive action is, no doubt, one of the most essential aids to such economy. But it will be better, in the case of small engines, to trust to lap on the valve and throttling the steam. If an engine be throttled by partially closing the throttle-valve, then it is plain that, although at the beginning of the stroke, when the piston is moving slowly, the full pressure is maintained, yet as the middle of the stroke is approached, where the piston moves more rapidly, the pressure within the cylinder must necessarily fall; since the opening, though of adequate size to maintain the full pressure on a slowly moving piston, is too small to maintain the pressure when the piston moves rapidly. As the end of the stroke is approached, the pressure will again rise from the slower motion of the piston there obtaining. But if, when the pressure begins to rise, such an amount of lap is given to the slide-valve as to shut off the steam altogether, then we shall be enabled to obtain a high rate of expansion in such an engine, the first portion being obtained by throttling, and the second by cutting off. No doubt there is a loss of power by friction when steam is throttled. But even here the loss is more apparent than real; for the friction generates heat, and goes to superheat the steam. While, therefore, in the case of large engines it may be advisable to introduce expansion valves, as a more perfect action may be obtained by their agency, it is right that we should know that such valves are not needed even to obtain high degrees of expansion, and that, in the case of small engines, any benefit derivable from them will not balance the complication. Gridiron valves, which enable a large amount of lap to be introduced without contracting the passages too much, or inconveniently increasing the throw, will be an eligible expedient in some cases, and the amount of expansion may be varied by altering the throw of the valve, which may be done by a slotted lever or other obvious expedients.

In most of the French portable engines, instead of the cylinder being bolted upon the boiler in one place, and the crank pillow-blocks in another, a cast iron frame is introduced upon the top of the boiler, on which the cylinder and pillow-blocks are fixed. This, no doubt, is a more mechanical arrangement than that which usually obtains in our portable engines. In many of the French boilers, moreover, the furnace and tubes are so connected into one piece that the whole can be withdrawn in a mass for cleaning or repairs, merely by undoing the bolts at the front which connect the front plate of the boiler with the shell. In these boilers the back end is hemispherical, as it cannot receive any support from the tubes or from internal stays. In England boilers have been made on this plan by Ransome and others. But they are not so common as is desirable, and judging from the numerous examples of this mode of construction presented at the Exhibition, the benefits of the system are more appreciated by the French than they are by us.

The governors in the French engines are but rarely of a simple character, nor are they usually driven in a simple manner, but the apparatus is beset with rattletraps in many cases. Sometimes an air-governor, in which air is forced into a cylinder by a pump, and raises a weighted piston, is used. The piston is connected with the throttle-valve, and when, owing to the accumulation of the air in the cylinder from the pump delivering more air than the outlet orifice is able to deliver, the piston rises and shuts the throttle-valve. This species of governor is by no means new, but its action is efficient, and it may be usefully introduced in some cases, and especially in steamboats. A good many governors are introduced with four balls, many of them with springs, and some of them consist of a ring held obliquely by a spring across the axis of rotation, which spring is compressed as the ring seeks to place itself at right angles with the axis with a force proportionate to the rapidity of rotation. None of these governors are so simple or neat as Pickering's governor. Spiral gearing appears to be in greater favour with the French than with us, and it is often used for driving governors instead of ordinary spur or bevel wheels.

The symmetry of the French engines is, on the whole, inferior to that of our engines, and the proportions and workmanship are not quite so good. Much of the gearing, however, is excellent, and many of the toothed fly-wheels work with a smoothness and truth which it would be difficult to surpass. In some cases agricultural engines of a very cheap and simple character are exhibited, where the first objects are smallness of first cost and facility of reparation by a country carpenter or blacksmith. Albaret exhibits an engine of this kind on a platform in the main building. The cylinder and crank pillow-blocks are placed upon a sole of thick wood, and the connecting-rod is of wood encircled by a strap of hammered iron. The bearings throughout the engine are of wood, and the bearings at each end of the connecting-rod are tightened by driving in a wooden wedge at the centre of the connecting-rod, which sends its two constituent pieces of wood endways, so as to press upon the end bearings. The wedge is prevented from starting back by a split pin inserted into one of the holes drilled through the point of the wedge.

In some of the French fixed and semi-portable engines a condenser and air-pump have been added at the side—not properly incorporated in the machine, but introduced as an addition. Such an arrangement, though permissible as an addition to an old engine, is inexpedient in the case of a new engine, where it is better to have the air pump incorporated with the engine, and forming an essential part of it. It would be quite practicable to construct a condensing engine in which the discharge of the water would be effected by much simpler means than this. But in this Exhibition there is very little evidence given of the perception of new principles of operation, though the old are often ostentatiously expanded by tyros bursting with new-fangled admiration. The magnitude of the French display is much greater than might have been expected, and reveals the enormous industrial progress made during the present auspicious reign—a proof and a consequence of the national prosperity. In France the steam-engine has found a great and appreciating field, and the national ingenuity, no longer content with blind imitation, has been stimulated to attempt works of improvement. But in nearly every case the improvements which are good are not new, and those which are new are not good. The attempts to improve have proceeded on too narrow a basis of pre-existing knowledge, and contrivances are consequently exhibited and paraded which in England would obtain no toleration at all. In France the steam-engine is at present in pretty much the same kind of condition which it was in England when it first issued from the preserves of Boulton and Watt. Then every English engineer had his crude ideas of improvement, which more extended knowledge and experience compelled him to abandon; and French engineers have, in like manner, hit upon many expedients now which they consider to be improvements upon pre-existing devices, but which, we may feel sure, maturer knowledge will induce them to give up."

The same journal—"Engineering"—has the following remarks on some of the engines in the French department of the Exhibition, which are very suggestive to engine makers in this country:—"We are among machinery—mechanical engineering of every sort. Familiar machines everywhere meet the eye. Surely we are in England; surely these are English engines driving English cotton machinery. No! all this is French. And what we must ask is the important question, Is it as good as our own? We fear we must answer, much of it is as good.

Let us take the first engine employed in driving this machinery. It is a pair of plain overhead beam-engines, set on cast-iron columns, called 60 horse power. The castings are good; the proportions strong; it looks like durability and honest work. There is no affectation of finish or refinement about it. Nevertheless, it is not an ordinary engine, and deserves study. Its valves are not driven by the ordinary eccentric, but by a triangular eccentric, little used, if at all, in England, and which has some good points. Moreover, this engine is a Woolf's engine, each engine of the pair having a high and low pressure cylinder set side by side. Both engines are worked by simple slide-valves, cutting off at two-thirds. Here, then, although there be little affectation of refinement, the manufacturer has an engine not only calculated to last and work, but one possessing more arrangements for working with uniformity and economy of fuel than are generally to be met with in ordinary English mill-engines. It is by Powell, of Rouen.

Further on we come to another engine of much the same sort—an overhead beam-engine; but it has more pretension, higher finish, greater symmetry of design. Though a single engine, it has Woolf's coupled cylinders. This engine has also refinements which fill the owner's pocket. It has a steam-casing; it works with a high degree of cut-off; and its governor regulates the speed, by the degree of cut-off, with good effect. It is by Lecouteux, of Paris. It is, like the former, a mill-engine, and is called 45 horse power.

Next we have an engine from Lille, of quite another sort. It is a plain horizontal condensing engine with a single cylinder, working expansively, but having the means of adjustment by hand to any degree of cut-off that may be desired. This is a sample of what we should call a 'good substantial job,' without pretence of any kind. It drives, as many of them do, by the toothed fly-wheel, has cased cylinders, and is of 65 horse power, built by Le Gavrian.

We now come on a sample from Mulhouse, by Ducommun—a compact, self-contained, we had almost said portable pair of engines, driving a small printing-mill, for patterns in six colours; a pair of cylinders, coupled on one crank-pin, of which sort there seem to be more samples in mill machinery than with us.

Lyons sends a sample of her engines, by Duvergier. It is a single condensing cylinder, horizontal, and of 30 horse power. It has a variable expansion gear, regulated by the governor in the following manner: first, there is the ordinary eccentric for the ordinary slide; next, there is a second eccentric for the cut-off valve. This eccentric moves a link, and the governor moves the end of the connecting-rod of the cut-off valve, up or down this link, till it gives the proper throw, and thus varies the cut-off simply enough.

The large establishment of Graffenstaden, presided over by Baron Bussiere, sends an engine of sound design, high finish, and unsurpassable execution. This engine is surrounded by samples of the tools by which it was made. One feels here as if one were in Whitworth's shop, for all around are tools evidently after Whitworth, but of which even he would not be ashamed. There is here a gigantic planing-machine of great power and high finish. The engine is worthy of the tools which made it. Large bearing surfaces; no stint of material. Strength, finish, and durability seem to be aimed at and accomplished. It is of 35 lbs. horizontal condensing. It cuts off to a high degree, and varies the degree of expansion by the governor. This expansive gear has all its mechanism exterior to the valve-chest, is very elegant, and well worth study.

Without going on further for the present with these French engines, we have said enough to induce our readers, when they go over, to study the French steam-engines used for driving their mills and manufacturing machinery with care and attention. They evidently have taken great pains to combine excellence, durability, and economy even at some expense of simplicity. Their frequent use of Woolf's system—their great use of high-pressure steam, working expansively—their very common and effectual employment of the governor to produce uniform velocity under very varying conditions by the regulation of the variable expansion—all indicate a general tendency in the French mill-owners to encourage and to pay for improvements, and in the body of French engineers to introduce the refinements of theory into the ordinary work of daily manufacturing industry. Such symptoms deserve our serious consideration."

(*f*) *The Corliss Engine.*—In the American department this engine attracted very great attention, not only from the novelty of its arrangement, but the remarkably fine character of the workmanship. The following remarks upon it we take from the "Engineer" of May 10th, 1867. "The English and American sections of the French Exhibition each contain specimens of engines fitted with the Corliss valve, but with different disengaging arrangement for working it. The American engine is a splendid piece of workmanship, but has not yet been put in motion, and at first sight, at least the gear for moving the valves, appears to be much heavier and more complicated than that of Messrs. Inglis and Spencer, as applied in the smallest horizontal engine by Messrs. Hick, Hargreaves and Co., of Bolton, which we illustrate above. Most of our readers are doubtless familiar with the Corliss valves, which are placed in small transverse cylinders at each end of the steam cylinder, the inlet valve above and the exhaust below, the port consisting of a long slit in the bottom of the transverse cylinder for steam, and in the top of the lower ones for exhaust, and closed by a valve, whose motion is lateral, for a sufficient arc of the circumference of the valve cylinder to enable it alternately to open and cover the port. The essential principle of this valve consists in the mode in which it is shut by an instantaneous motion the moment the required amount of steam has been admitted into the cylinder, and if its action is perfect it should practically obviate all wire drawing. The cut-off is also easily placed in connection with the governor, and thus the great desideratum of varying the expansion constantly in proportion to the work to be done is arrived at. We will now describe the manner in which Messrs. Hick and Hargreaves, carrying out Messrs. Inglis and Spencer's designs, have succeeded in applying the Corliss principle.

In our first cut, an elevation of the engine on the side to which the valve gear is attached, there is shown a small horizontal cylinder, partly hiding the hand wheel of the throttle valve. From each end of this issues a small brass trunk piston, acted upon by a spiral spring within the cylinder, which if left to itself would keep the trunk pistons constantly pressed home into the cylinder at their respective ends. From these trunk pistons proceed two connecting rods, each working a lever staked on the axis on which the valve reciprocates. To a pin at the lower end of this lever is attached one end of a rod, the other extremity of which works upon a stud at the back of a circular disc, to which is communicated a reciprocating motion through a small arc of a circle by the throw of the eccentric rod acting on a stud near its circumference, as will be seen in fig. 1. (not given here). The action of the eccentric if left to itself would be to open and shut the valves at a uniform speed, by the rocking motion given to the disc and communicated back from it through the rods we have mentioned as attached to the studs behind it, which in their turn rock the levers on the valve spindles; but, as will be seen by reference to the enlarged view of this part of the machine, the connecting rods between the disc and the valve levers contain a disengaging arrangement, by which the portion of the rod, consisting of a spring steel fork, is at a certain point in the stroke disengaged from the part of the rod connected with the valve lever. The point of the stroke at which this disengagement takes place is exactly that at which it is desired to cut off the steam; and the lower end of the lever being free, it is suddenly chucked back by its upper end, which is connected with the spring moved trunk cylinder above described, and which is called a 'dash-pot.' The moment at which this disconnection shall take place is regulated by the governor, the rod from which acting on two short cranks immediately above the disc, connected by toothed segments, determines the motion of a cam, which opens the steel fork of the connecting-rod, between the valve lever and the disc, exactly at the right moment.

It will easily be seen that the action of the governor rod is to shorten or lengthen the distance of the pin of the cam crank from the centre line of the cylinder, and thus shorten or lengthen the period for which the valve spindle lever is acted upon by the eccentric, or in fact the period for which the valve is made to continue its opening motion; the instant the cam is brought into play and the fork separated, that moment the eccentric ceases to act on the valve, which is shut instantaneously by the 'dash-pot' arrangement. In order that the two trunk pistons shall not strike too violently when taken home by the springs, a cushion of air is left behind them which only slowly passes through a small hole and eases the back blow. A somewhat similar arrangement is adopted to prevent the sudden fall of the governor balls; their weight is taken by one end of a lever, the other end of which is attached to a piston working in an open cylinder full of oil; a small hole in the piston only allows the oil to pass through at a regulated speed, and thus gradually lowers the governor balls in the case of sudden change of motion.

The general design of the engine will easily be seen from our engravings, and we have only to add that it is admittedly unsurpassed in workmanship and performance by any engine in the building. The crank and shaft are of Bessemer steel, and the engine is of 16-horse nominal power, but, as they would say in Ireland, large for its size."

(*g*) *Steam Engines for Winding and Pumping.*—From one of the reports, issued with the sanction of the Department of Science and Art at Kensington, we take the following:—"If there were any one department of machinery in which we Englishmen used to think, a few years ago, that we had it all our own way, it was the construction of steam-engines. And although it might be conceded that taste was to be found across the Channel, and that good designs might be produced, and perhaps, even light work executed by French and Belgian engineers, still it was confidently asserted that for heavy work and for powerful engines, they must come to England. A glance at the Paris Exhibition will dispel these illusions, and teach us that machine makers and designers have arisen who have made good use of a sound education in mechanics, and who are competent to cope with the tasks daily brought before them by the progress of engineering.

Several large winding-engines for collieries are brought before us in full size, and exhibit the types which are now attached to some of the first-class works. Thus, M. Quillacq has erected an engine with two coupled vertical cylinders in front of the pit-frame of the Bethune Company, the piston-rods acting directly on the shaft of the drum or rope-roll. Belgium has sent two double-cylinder engines, each, like the last, of about 200-horse power. Both these, that exhibited by the Chatelineaux Company, and that of MM. Dorzée and Andry (Belgium, 19 and 6), have their cylinders mounted on a pyramidal iron framing, and working downwards upon the rope-drum, which is placed at the level of the ground. Something may be gained by this mode of construction in the economy of the engine-house, but several reasons might be adduced in favour of the opposite system, generally followed at our large collieries, of planting the cylinders low and mounting the drum above. These engines, as also the well-finished, powerful, horizontal machine exhibited by the Creusot Company, are fitted with a special cylinder for a steam brake, and sometimes with an apparatus for arresting, independently of the engineman, the progress of the cage on its going dangerously high in case of inattention. One of these contrivances, a long horizontal screw, along which a carriage travels as the cage ascends, was already exhibited in 1862 by the maker, M. Gouteaux, of Gilly.

Some modifications of pumping-engines, which evince much ingenuity, are exhibited in drawing by M. Colson (Belgium, 5), but their merits can scarcely be pronounced upon without observation of their effectiveness in practice. The French engine-maker, M. Quillacq, of Anzin (Nord), not only exhibits his productions in drawings and actual engines, but excited the incredulity of some of the jury by a statement that he had supplied both pumping and winding steam-engines to an important Newcastle colliery. That such a Gallic invasion of our great centre of colliery operations should have taken place without some special reasons or private arrangement appeared highly improbable, and I at once communicated with the owner for the purpose of obtaining the explanation. It is but justice to the French engineer to state that the order for the direct-action pumping-engine which he supplied was given simply in consequence of his lower price and better finish as compared with the tenders from English houses. It has now been at work above eighteen months, and I quote the particulars kindly sent me by the owner in saying that 'it has given the greatest satisfaction,' and that 'the construction and the quality of material and workmanship are very good.' This has led to the order of a pair of winding engines for the same place, which are also 'highly satisfactory.' Here we have, then, one of our Newcastle mines actually working by means of French-made machinery, fairly brought in by open competition to the midst of our machine shops and foundries; and when we look at the inland position of Anzin, and the unquestionable disadvantages which have to be combated in a district where coal and iron are comparatively dear, I cannot but think these results redound to the credit of French engineering, and inculcate on ourselves an important lesson."

38. *Pumping Engines for Town Water Supply.*—The following paper under the above title was read before the "Society of Engineers" at their meeting, April 1st, 1867:—"It is an admitted fact, with the majority of engineers, that the Cornish or single-acting engine is capable of developing a far greater percentage of work from a given weight of steam than any other type of engine employed for pumping purposes, when employed under similar conditions. Nor is it always necessary to qualify the statement with the words *similar conditions*, but it is often found that a well-constructed Cornish engine does a higher duty when expanding the steam nine times than a rotary engine expanding the steam eight or nine times; and, as an obvio

consequence, it follows that the peculiar element of economy existing in the single-acting engine is not dependent on the ratio of expansion employed, but in the mode of developing and applying the power. Notwithstanding the advantages which it possesses over its rival, the Cornish engine has not received the amount of attention of late years which has been bestowed on the rotary engine, and in order that the latter engine may produce the maximum economy, recourse has been had to high expansive working, to obtain which the crude ideas of Hornblower and Woolf have been developed, a second cylinder has been applied, and the ratio of expansion increased with very good results accruing. It appears rather strange to the author that the inferior type of pumping engine should have been selected as the type to receive a higher state of development, and it is this, together with the dictates of experience which he has had with single-acting engines, which induced him to prepare this brief paper for discussion.

The gear of a single-acting engine requires nice adjustment and more intelligent supervision than does that of its rival, which is probably one reason why the rotary engine is often preferred; it is also easier to apply the latter engine to a variable load. But a massive fly-wheel and sweep-rod appear to the author to be *out* of place in a pumping-engine; for it not only requires a large amount of extra space, but the moving parts are greater in number; it requires more frequent repairs, and its period of duration as a natural consequence is very much shorter. The chief reason for the durable nature of the Cornish engine is the fact that all the working parts are made very massive. It is a great mistake to make an engine light and liable to derangement for the sake of economising a few tons of metal, especially so for water-works purposes, where it is of great importance that repairs should be few, and the engine made lasting.

The author regards it as an axiom that the single-acting engine possesses a peculiar element of economy, and he would now make a few suggestions towards a higher development of the type, and a peculiar adaptation to water-works purposes. Of the two types of single-acting engines, the beam engine is considered by the majority of engineers, probably, as superior to the direct-acting engine, and it certainly is, inasmuch as, by the employment of a massive beam, the inertia of the extra amount of matter to be put in motion enables a higher degree of expansion to be employed, and also renders the motion of the piston more uniform. But the direct-acting type possesses certain other advantages, and when employed to pump against a great head of water, with a single-acting pump, the weight of matter required to displace the water in the pump is sufficient to enable a ratio of expansion of from four to five to be employed. A well-constructed Cornish engine will work much sweeter than a double-acting engine of the same power. There are no bearings in the former engine to be repeatedly thumping; the moving parts are rigid, and as long as the catchpieces are kept from contact with the spring beams, the motion of the piston is free from vibrations at a mean speed of 300 ft. per minute, or a maximum speed of 600 ft. The author is acquainted with many direct-acting engines, with 10 ft. stroke, making 15 strokes per minute in regular work.

The great advantage attending this class of engine is that it possesses but few moving parts to keep in repair, and is very far less expensive than the beam engine; also requiring small and, therefore, less expensive buildings. It has occurred to the author, that if the direct-acting type of engine can be employed with a ratio of expansion of 9 or 10, and an initial pressure of 60 lb. to the square inch, without risk of injury to the machinery, very economical results would follow; such a result cannot be obtained with a single cylinder. The author has endeavoured to prepare the outline of a design, the object of which is to enable the former conditions to be complied with, by the employment of a second cylinder, thus obtaining a maximum ratio of expansion, without dispensing with the peculiar element of economy embodied in the single-acting engine, and in doing so he has had six objects in view.

1st. To reduce the blow impressed on the piston, consequent on a high degree of expansion in a single cylinder.

2d. To increase the power developed on a unit of surface of the piston.

3d. To isolate as far as practicable the cylinders from the frigerific influence of the condenser.

4th. To reduce the steam space between the two cylinders to a minimum.

5th. To obtain a nearly continuous flow of water with single-acting pumps. And, 6th. To adapt the engine to the requirements of a variable load.

In order that a high degree of expansion may be employed, the author proposes to make the total initial in the high-pressure cylinder equal to 60 lb. to the square inch, and to expand the steam rather more than ten times, that the terminal pressure in the low-pressure cylinder may be equal to or slightly in excess of the pressure of the vapour in the condenser.

The drawing, No. 1 (not given here), represents an elevation of the proposed engine, and the drawing No. 2 a plan of the same. The two cylinders are placed each directly over a plunger pump, the plunger being directly attached to the piston-rod in the usual manner for direct-acting engines. The streams of water from the two pumps converge towards the main pipe, forming the letter V. An air-vessel is placed on each arm of the V, with a stop-valve between it and the plunger pump. The nozzles, containing the governor and steam valves, are placed at the foot of the small cylinder at the right-hand side. Between the two cylinders are placed the nozzles containing the steam equilibrium and eduction valves for the large cylinder. Immediately beneath the latter nozzles is placed the condenser and air-pump. It is easily seen from the drawing how easily the system admits of a compact arrangement, a 95 in. and a 60 in. cylinder only requiring a building 31 ft. 9 in. long by 25 ft. wide, from out to out.

In the proposed design the small cylinder is 60 in. and the large cylinder nearly 95 in. in diameter, which proportion gives a relative area of pistons of 1 to 2·5; and as the length of stroke is the same in both cases, the same relative proportion is true for the capacities. The steam is first admitted beneath the small piston, and at the completion of what is technically called the 'in-door' stroke, it is allowed to escape into the large cylinder beneath the piston, so that the 'in-door' or up stroke of one piston is performed during the 'out-door' or down stroke of the other, by which means the two plungers are made to perform the function of a double-acting pump. It is evident that the mean effective pressure on the small piston must be 2·5 times that on the large, since 1 to 2·5 is the relative areas of the two cylinders. The two plungers being of the same diameter, the author proposes 9·9 lb. as the mean pressure in the large cylinder. This having been decided, it is at once evident what must be the initial pressure. Steam expanded 2·5 times, with a mean pressure of 9·9, must have an initial pressure of 13 lb. It is also evident that the mean effective pressure in the small cylinder must be 9·9 × 2·5; but since the small piston, during its down stroke, is subject to a mean back pressure of 9·9, it follows that the total mean pressure must be 9·9 × 3·5, which is equal to 34·6 lb.; for the author proposes not to employ an equilibrium valve for the small cylinder, for reasons which will soon become apparent.

The initial pressure may be anything in the small cylinder above 34·6 lb., and the point of cut-off must be such as to give that as the mean pressure. The author proposes to employ much higher pressures than is usual for single-acting engines, say 50 or 60 lb. initial. With 60 lb. initial, the steam must be cut off a little before $\frac{1}{4}$ of the stroke is completed to give a mean pressure of 34·6 lb. The greatest economy would unquestionably arise from the employment of the higher pressure; but the blow imposed on the piston would of course be greatly augmented, but not so much as to offer any obstacle to the use of high pressures, the unfettered state of the piston preventing the shock which would otherwise occur.

Taking the mean of the two mean pressures, we have 17·3 as the total load on each square inch of the collective area of the two pistons, and in this particular the author has but slightly increased the power developed on each unit of the area. It is usual to put a total load of from 14 to 15 lb. on the square inch of the pistons of Cornish engines; but it must be remembered that the ratio of expansion is more than double in the proposed engine than is usually employed.

The small piston being subject to a mean back pressure per unit of surface equal to the mean effective pressure on the large piston, it follows that the former piston must be loaded to 2·5 × 1=3·5 times the load per unit of surface of the large piston, the effective load on the two plungers being the same in both instances. The small piston requiring the extra load to overcome the back pressure in the 'out-door' stroke. This can be accomplished by putting the extra load in dead weight on the plunger, but in such a case the top of the cylinder must be kept free from pressure, demanding a communication with the condenser.

The author's object is to isolate as much as possible the cylinders from the condenser, and therefore to prevent any communication with the condenser, except to the top part of the large cylinder. He proposes to employ a steam cushion in the top part of the small cylinder, having a mean pressure equal to the mean effective pressure on the large piston, and to make the loads on the plungers equal. Then although the relative areas of the two pistons are as 1 to 2·5, and the mean pressures are as 1 to 3·5, yet the mean effective pressures are as 1 to 2·5, the remaining pressure in the small cylinder being employed in compressing the steam forming the cushion during the up stroke, which is given back again in overcoming the back pressure during the down stroke.

The action of the steam in the cylinders will readily be understood by reference to the diagram No. 3. Fig. 2 represents the capacity of the small, and fig. 3 the capacity of the large cylinder. The vertical scale represents the pressures. The steam in the small cylinder has an initial pressure of 60 lb. to the square inch. The point of cut-off is a little less than one-fourth the stroke, giving a terminal pressure of about 13 lb. to the square inch. The steam valve is then opened between the two cylinders, and the steam contained below the piston of the small cylinder is admitted below the piston of the large cylinder; but during the up stroke of the small piston it has to encounter the cushion represented at the right-hand side of the figure 2, and the work expended in cushioning the steam is given back again during the down stroke. It will be seen that the condenser has no communication with the small cylinder, where the difference in temperature would be the greatest. The liability of the catch pieces striking the spring beams is greatly decreased by the employment of the steam cushion. Fig. 1 represents the pressures in the large cylinder during the stroke. It is noticeable that the curve in fig. 1 is not a continuation of the hyperbolic curve in fig. 2 on the left-hand side, and the reason is obvious; for if we put c to represent the capacity of the small cylinder, and $2·5c$ that of the large, and p any portion of the stroke, then if I be employed to represent the initial pressure, we have for the pressure at any point, p, of the stroke

$$x = \frac{1}{\frac{c}{p} + \frac{2{\cdot}5c}{p_1}}.$$

The valve gear of the Cornish engine, as commonly in use, forms no mean item in the cost of the engine. It has occurred to the author that there is room for simplification; he has therefore endeavoured to arrange the valves in his proposed engine so as to admit of its being done. For the proper distribution of steam in the two cylinders, five valves are necessary; first, the governor-valve, which is actuated by hand; second, the steam-valve for the small cylinder; third, the steam-valve for the large cylinder; fourth, the equilibrium-valve for the large cylinder; and fifth, the eduction-valve for the same. The steam and equilibrium valves last mentioned admit of being placed in one nozzle, since they both communicate with the same steam-port, but instead of placing them side by side, as is usually done, the author proposes to invert the equilibrium over the steam-valve, and to pass the spindle of the latter through a hollow spindle provided on the latter, thus enabling the simple gear shown on drawing No. 4 to be employed. The arrangement shown in the drawing is designed to give no pause at the end of the stroke, and, consequently, no cataracts are represented; but if it is desired to produce a pause, it is only necessary to apply cataracts to the quadrants shown in the side elevation. The author would propose to have three of those pillars, one arranged to two valves, and the other two each for single valves, thus completing the set, instead of the complicated arrangement generally adopted. As this is merely a matter of detail, it may be dismissed without further notice. The fact that the steam is passed from the foot of one cylinder direct to the foot of the other enables the steam-ports to be reduced to a minimum. The cylinders also admit of being placed nearer together than shown in the drawing, so that the space occupied by steam space is merely nothing but that occupied in the nozzles themselves.

It is an admitted fact that a single-acting engine works under the most favourable circumstances when employed to pump with a plunger pump. There is also an advantage connected with the type of pump itself. It is the most simple, the least liable to get out of order, and requires the least attention; but there is the disadvantage of an intermitting flow of water. In the author's design the two plunger pumps perform the function of a double-acting pump, without the disadvantages attending the latter.

The hydrostatic column against which the engine has to pump, in supplying water to towns, often varies very considerably, and it therefore becomes very important that a means should be provided for adapting the engine to a variable load. If the pump employed be of the plunger type, the load per unit of piston is constant; and should the hydrostatic column become less than that for which the load is designed, the load should also be reduced in the same proportion. Since the down stroke of one piston and the up stroke of the other are to be performed simultaneously, according to the author's design, it is evident that if the surplus power exerted in the down stroke of one piston can be transmitted to the ascending piston, the engine is then adapted for a variable load. This is proposed to be accomplished in the following simple manner, as shown on the drawing No. 5: Descending from the cross-head of the plunger are two rods, or small plungers, entering small cylinders on the sides of the main pump; these cylinders are all connected by means of pipes, and are to be kept filled with water. Then any extra load on the descending plunger, above that necessary to overcome the hydrostatic column and the friction, is at once transmitted through the water contained in the small cylinders just described, to the ascending plunger, provision being made for the varying speeds of the pistons in various parts of the stroke by means of a small ram and cylinder attached to the pipes connecting the other cylinders. The small ram just alluded to should be of sufficient weight to descend freely under the influence of gravity when the rams attached to the cross-heads of the main plungers cease to exert a pressure on it through the water. The objects thus to be gained are two: first, to keep the pipes and cylinders filled with water under the varying speeds of the two pistons; and, secondly, to compensate for any leakage which might occur through the stuffing-boxes. It is obvious, that as the up stroke of one piston and the down stroke of the other take place simultaneously, the velocities during the former part of the stroke must differ greatly.

The drawing No. 5 represents one pump-plunger up and the other down.

If the plungers are loaded beyond that necessary to overcome the head of water plus the friction, the extra load is brought to bear on the small plunger A, and transmitted through the water to the plunger B. The plungers being of the same diameter, an equilibrium of pressures results. If the plungers moved at equal velocities at all points of the strokes, then would the pressure transmitted from one plunger to the other remain constant; but if the velocities vary, the pressure becomes intermittent. At the former part of the up stroke the piston acquires its greatest velocity, whilst at the former part of the down stroke its speed is the least; it therefore follows that no pressure is transmitted during the former part of the stroke, consequently the mass of matter to be put in motion by the entering steam is greater than that required to displace the water in the pump, the inertia of the additional matter rendering the motion more uniform. At the same time the pressure is removed from the plunger B, and the full load is brought to bear on the descending plunger, in the former part of the stroke, just when it is wanted to overcome the inertia of the water.

As the ascending piston approaches the end of its stroke its velocity decreases, whilst the velocity of the descending piston increases under the accelerating influence of gravity, until the two masses have acquired the same velocity, when the *vis viva* of the descending mass is transmitted through the water to the ascending mass, and the latter part of the strokes becomes synchronous. The amount of energy due to the overplus load in the down stroke of one mass is transmitted to the ascending mass when the two pistons are brought to a state of rest, with no loss of energy resulting. A moment's reflection will suffice to show that the contrivance which the author has just described constitutes a hydraulic beam, which enables the stroke to be performed (in fact, compels) in equal times, and still allows the pistons free to move with varying velocities at different portions of the stroke, thereby preventing the undue strain which is thrown on the piston and its attachments when a weight of steam is suddenly admitted on the piston without its being able to move freely under the pressure, as is the case with all double-acting engines with a fly-wheel.

To make the action and use of the hydraulic beam more readi understood, the author gives the following example: Supposing the engine shown on the drawing No. 1 to be designed for a maximum lift of 300 ft. and a minimum of 200 ft., then the weight to be put on the plunger would be 70,173 lbs. plus the friction, the plunger being 26 in. in diameter, which is the weight necessary for the 300 ft. lift.

If the lift be reduced to 200 ft., the extra 24,550 lbs., which is the weight beyond that required to displace the water in the pump, is extra dead weight transmitted from the descending to the ascending mass, and the weight of steam required is proportionally decreased.

The chief objection to the direct-acting engine is that the mass to be set in motion at the commencement of the stroke is less than that with a beam engine, consequently the motion of the piston is not so uniform when employed with the same ratio of expansion, which arises from a less amount of inertia in the moving parts. The hydraulic beam would enable a much greater weight to be put on the plunger than is now done, and the velocity of the piston would be rendered more uniform, whilst no loss of energy could arise from the engine not being accurately weighted."

39. *Hints for Inventors on Steam Condensers.*—The two following articles are from the "Scientific American" of dates Feb. 2d, 1867, and May 4th, 1867, respectively:—"The connection of condensers with steam engines seeks, in general terms, to subserve one of two purposes, viz.: (1) either the reduction of the vapour to fluid that it may as such be returned to the boiler, or (2) the restoration of it to the water state that it may be devoted to some other use.

The problem submitted to invention for solution under the first head, is to effect the condensation at the highest possible temperature, and to return the product to the boiler as near the ebullition point as attainable. The conditions under which these two ends can be accomplished are to be met in the apparatus, and to realize them is the task which mechanical and chemical talent has proposed to itself. He who comes nearest a full satisfaction of these *desiderata* will give the world a most valuable invention. In all attempts to reach these results, there are some well-settled facts to be borne in mind. Among them are the following:

That water contains a large quantity of air in a state of solution, and that by boiling it this air may be liberated, so that the liquid contains less than any assignable measure: that water freed from air will not boil at all, but at 260° Fah., or thereabouts, explodes into steam with destructive energy: that water in this state, and at the temperature noted, will burst into steam if so much as a drop of the fluid in its natural condition be thrown upon it.

These are facts familiar to the manipulations of the laboratory. Others belonging to the same family are as follows: that water in being crystallized is deprived of every atom of air—hence ice possesses not a particle of it: that ice, melted under oil to exclude the atmosphere, does not, upon taking the liquid form, boil at any temperature, but explodes with violence at about 260° Fah. These are facts not so familiar, but nevertheless well established and incontrovertible.

Related to the subject before us, and therefore embraced in the investigations of the inventor, are also the ensuing: that all fresh water used in boilers is impure; *i.e.*, invariably consists of something more than hydrogen and oxygen combined: that in heating it, the acid and alkaline matters existing or evolved form salts, which present themselves in solution or in incrustation: that in boiling it, the air contained is slowly set free and mingled with the gases generated in the formation or by the resolution of the salts: that upon depriving water of its air, the adhesure of its particles seems to be greatly intensified, and its elasticity destroyed, insomuch that a stream of it poured into a glass tube gives a peculiar metallic sound.

In the presence of these three series of facts, it becomes us to inquire whether a steam condenser, which collects and returns to the boiler the vapour that the engine discharges into its exhaust, will not gradually separate the air incorporated with the water, and thus (*a*) steadily advance the point at which steam can be raised from 212° to —° Fah.: and (*b*) finally at 260° Fah., cause an explosion of the boiler.

Another question, not yet answered by invention, though intimately blended with this, is, whether by any means within practicable reach, the air set at liberty by ebullition can be re-combined with the water, and thus preserve the liquid in its normal status

In most condensers of the kind under review, provision is made for the escape of the gases generated by the impurities of the water, and with them, of the air upon which the vitality and safety of the fluid depend. Could not these gases be discharged without carrying the air with them? Or could they not be absorbed without taking up the latter also? These are practical and important inquiries to meet and satisfy.

If a steam engine could work without loss a condenser without leakage, and thus return to the boiler all the water originating from it, the probabilities are that it would prove a source of serious apprehension, and not be a desirable thing under any circumstances. Hence another question arises, and that is, How much water in its natural state should be supplied to the 'fountain of power' under assigned conditions, to prevent the boiling point from approaching too near 260° Fah.? or rather, At what figure on the sliding scale from 212° to 260° Fah. should ebullition be secured, in view of the greatest economy of fuel and of the highest safety of operation?

From these considerations it would appear that the more complete the condensation, where the water is restored to the boiler, the higher the ebullition point rises above 212° Fah.: that as this point ascends the scale of 48° the temperature at which the water can be returned to the boiler should be increased; and lastly, that the thermal line, if we may be allowed the expression, on which the steam will condense, passes upwards correspondingly toward 212° Fah. SUGGESTOR."

40. *Hints for Inventors on Steam Condensers.*—" MESSRS. EDITORS,—In the article under this caption, published Feb. 2d of this year, two important facts were presented, viz.:—

(1.) That upon depriving water of the air incorporated with it —in other words, in distilling it—it is rendered incapable of ebullition, and upon converting it into steam in this condition it explodes with force.

(2.) That this explosion takes place not at the boiling point, but at 45° to 75° F. above it—generally at about 260° F., though frequently not under 300°.

Upon these data, well established by Donny, Tyndall, and other experimenters, it is assumed:—

(*a*) That if a condenser enforce or permit the escape of air from its vacuum, it should, on the contrary, provide for its impregnation with the 'feed' to supply the loss and to preserve the normal status of the water.

(b) That all gases, oils, etc., corrosive or explosive *per se*, or rendered such by combining with air, or each other, should be discharged, absorbed, or otherwise disposed of and disarmed.

If condensers are not constructed in subjection to the first principle (*a*) set forth, they increase the liability of boilers to burst, for they tend to exhaust the 'feed' of its air, thus carrying the boiling point above its legitimate place, and approximating it to that of explosion.

To illustrate: if upon trial, with the engine at rest, the pressure in the boiler is found to be only 30 lbs. to the square inch, while the temperature of the water stands above 241° F., say at 300°, the engineer should apprehend imminent danger, because it is evident that the heated liquid is nearly freed of air, and may at any moment be converted into steam with destructive energy. The injection of cold water into the boiler at such a crisis would instantly precipitate the catastrophe.

In the face of these facts, every boiler, whether working with a condenser or without one, should have delicate and accurate instruments attached for registering two things, viz., the *pressure* of the contained steam and the *temperature* of the water under it. A thousand disasters charged to high pressure—unequal expansion and contraction, hot flues, gases, oils, etc.—might thus be readily avoided, or traced home to their true cause.

The following table may be of use to novices or sceptics in conducting experiments in this direction entitled to confidence:—

PRESSURE AND TEMPERATURE OF STEAM.

Pressure in lbs. per sq. inch.	Corresponding temperature, F.	Pressure in lbs. per sq. inch.	Corresponding temperature, F.
15	212·8°	130	352·1°
30	251·6°	150	363·4°
45	276·4°	170	373·6°
60	295·6°	190	382·9°
75	311·2°	210	391·5°
90	324·3°	230	399·4°
110	339·2°		

From this table it may be observed that when the pressure is that of the atmosphere (15 lbs.) the temperature of the water is at about 212° F. It should, however, be borne in mind that these figures are not correct when the water is not quite pure. Thus, if common salt be added the boiling point, under the 15 lbs. aforesaid, ascends to 224° F.; if the liquid be saturated with nitrate of potash, it rises to 238°; if with chloride of calcium, to 264°, and so on.

Hence the importance of knowing the condition of the water used, and of relieving it of impurities. Whatever carries the boiling point above its true level, under assigned pressure, causes undue consumption of fuel and may provoke alarming consequences.

If condensers are not constructed in subordination to the second principle (*b*) laid down, the explosive and corrosive gases, oils, and other agents generated or introduced, may inflict serious injury by accumulation or combination, and expose the boiler to convulsions or explosions. Hence full and effectual provisions should be made for ridding the vacuum of these facile and refractory elements, and thus guaranteeing the purity of the feed water on the one hand and its integrity on the other.

From these considerations it would seem that inventors in this field should aim to produce condensers—

1st, Which free the steam of all obnoxious and explosive constituents, or which, by combining with each other or with air, may be rendered such;

2d, Which restore to it or the feed water the air lost from any cause, thus preserving the 'feed' in a normal condition with respect to its constituents of air and water.

From these considerations it would also seem that manufacturers and others, who make or use boilers or condensers, should look well to their plan of construction and their system of operation, not only in contemplation of safety but of interest.

Have we boilers constructed with the *registers* noted attached?

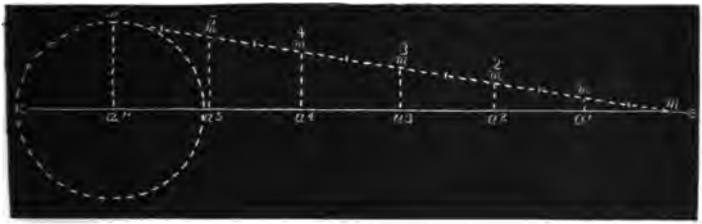
Have we condensers built in conformity to the two principles above enunciated? SUGGESTOR."

41. *Counterbalancing Reciprocating Engines.*—"The perfect counterbalancing of the momentum of the reciprocating parts of an engine in a *horizontal direction* is often a matter of considerable importance, especially when the engine is required to work at a high speed. It is seldom, however, that this is successfully

carried out, except in horizontal engines, from the fact that the manner in which it can be accomplished is not at first sight apparent. We propose, in the present article, to give a complete discussion of the elements involved in this problem, and to deduce a simple and direct method by which the horizontal momentum of any engine, inclined or vertical, as well as horizontal, may be properly counterbalanced. We have intimated already, that it is only with reference to a horizontal direction that the subject is to be considered, since, in general, it is supposed that an engine is so firmly secured as not to be influenced by a force acting in a vertical direction, while it is to prevent all tendency to horizontal swaying that the counterbalance is supplied.

Let us, in the first place, consider what it is that causes this tendency to motion in the direction of the centre line in an unbalanced engine. Disregarding, for the present, the effect of the connecting-rod, we have the fact that, when the crank is at right angles with the centre line, the reciprocating parts are in motion with a maximum velocity. If uncontrolled by the crank-pin, they would, of course, continue to move forward in a straight line at the same velocity, and would oppose a resistance to any body tending to arrest their motion. Such a body is the crank-pin, and accordingly, during the last half of the stroke, a pressure is exerted upon that part, the amount of which will depend on the mass and velocity of the reciprocating parts. Having brought the parts to rest, it is now necessary to set them in motion again in the opposite direction, and to do this will require exactly as much work as was absorbed in arresting their progress before. If, for simplicity's sake, we regard the crank-pin as the motor, which we may do without changing in the least any of the facts involved, we see that the pressure on that point while bringing the parts to rest, and that while starting them into motion, is continually in the same direction, so that we have, during the whole of the half-revolution of the crank, from its position at right angles to the centre line, on one side, to the same position on the other side, a pressure exerted in the direction of the end of the stroke which lies in that half-revolution. The same is, of course, equally true of both half-revolutions of the crank from the dividing line at right angles to the centre line. The point which we wish to call attention to is, that it is not the velocity, but th *change of velocity* that gives rise to pressure, and which, therefore, needs to be counteracted. In the case of an engine in which the power is taken off from the shaft on the other side of the pillar block from the crank, as is almost universally the case, whatever pressure is applied to the crank-pin is transmitted directly to the pillar block, and hence the effect of this alternating force a[illegible] from the changes in velocity of the reciprocating parts, in[illegible] ducing a bodily motion of the whole engine. Now, to p[illegible] this in a horizontal engine, we place a weight equal in mag[illegible] to that of the reciprocating parts opposite to the crank-pin, [illegible] at an equal distance from the centre of the shaft; so that [illegible] changes produced in its velocity *horizontally* may at all times [illegible] equal to those occurring in the reciprocating parts, and therefore exactly neutralize their effect. As, however, this mass moves in a circle, it exerts a pressure at right angles to the centre line at all points in its revolution, except when it coincides with that line; but as in this case this is a vertical force, we do not regard it. We resolve the centrifugal force of the revolving weight into its two components, at right angles to and parallel with the centre line in this manner, because this gives us at once a key to all the effects produced by the counterbalance weight. The component parallel with the centre line is exactly neutralized in its effects on the stability of the engine by the action of the reciprocating parts, the other remains unaffected. We see already, therefore, that this method of counterbalancing would not answer for an inclined or vertical engine, since this latter force would in these cases have a direction approximating to the horizontal, and would therefore give rise to a motion exactly such as we wish to prevent. But before proceeding to examine these cases, let us investigate the peculiar motion of the connecting-rod, partaking as it does of both a reciprocating and a rotary motion, and see how this is to be provided for. It is evident that the end immediately at the crank-pin will offer a resistance to any force or body which tends to vary its velocity in the direction at right angles to the centre line, in exactly the same manner as a body revolving with the crank, or say the crank-pin itself, and this will, of course, in all directions of the centre line, horizontal or vertical, be perfectly counterbalanced by a weight placed opposite to it. Our first problem, then, is to ascertain what proportion of the weight of the rod is to be so allowed for. If we let A B, Fig. 66, represent the connecting-rod, supposing it also stripped of all extra weight

Fig. 66.



at either end, and considered merely as a plain bar, we may suppose it to be divided into any number of small or elementary masses of equal magnitude, *m m*, &c. It is evident that the velocity of each of these, when the rod coincides with the centre line, is proportional to its distance from the centre, A, and the amount of work stored up in each, being as the square of the velocity, will be represented by $\frac{1}{2}m_0 \times 0$, $m_1 a_1^2$, $m_2 a_2^2$, &c. Now, in moving to the position, A B, in which they are at rest, in this direction each point passes through a distance proportioned to its distance from the centre, and consequently the resistance which it offers during this motion to the force tending to bring it to rest will be represented by $\frac{m_m a_m^2}{a^m} = m_m a_m$, or, in other words, the pressure which it exerts will be proportional to the distance from the centre, A. These pressures are all sustained by the crank-pin at one end, and the slides at the other, and the proportion of each, which either of these bears, is in the inverse ratio of the distance of the moving masses from the sustaining point, or in the direct ratio of its distance from the opposite end of the rod. The pressure coming on the crank-pin, therefore, will be represented by $\frac{1}{2}m_0 \times 0 + m_1 a_1^2 + m_2 a_2^2 + \cdots + \frac{1}{2}m_n a_n^2$, or as the sum of all the elementary masses into the squares of their distances from the point, A. Calling the distance, A B, unity, and the sum of all the masses $\frac{1}{2}m_0$, m_1, &c., M, we shall have the sum of this series equal to $\frac{1}{3}$ M. From this, we find that the pressure on the crank-pin in a direction at right angles to the centre line resulting from the swing of a connecting-rod of uniform dimensions would be the same as that of a mass of one-third the weight of the rod situated at the crank-pin; and if we add to this the weight of the extra metal in the end of the rod at the crank-pin, we shall have the amount of weight which will be neccessary to counterbalance this motion of the connecting-rod, supposing it to be placed diametrically opposite the crank, and at the same distance from the centre of the shaft.

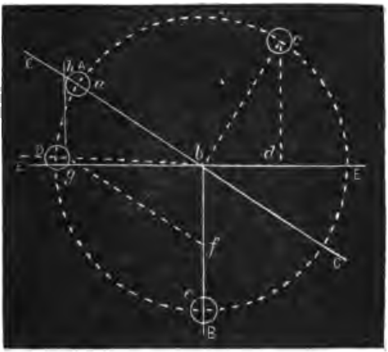
We have observed that a part of the pressure thus generated in the connecting-rod comes upon the slides. The portion of the pressure exerted by each of the elementary masses, m, so sustained, being proportional to its distance from the end, B, while the total amount of each such pressure is proportional to its distance from A, we shall have for the combined pressure of all the masses, m, the sum of a series of the form,

$$\tfrac{1}{2}mnp \times 0 + m(n-1)p\tfrac{1}{n} + m(n-2)p\tfrac{2}{n} + \ldots \tfrac{1}{2}m(n-n)p\tfrac{n}{n},$$

in which $p =$ the resistance offered by an elementary mass, m, moving at a unit's distance from the centre, A, n,· such units making up the length of the rod. The sum of this series we find to be ^{1} M, of the pressure on the slides due to the changing momentum of the connecting-rod will be equal to that which would be exerted on the crank, by a weight of one-sixth the magnitude of the plain part of the rod revolving with the velocity of the crank-pin. It is not necessary, in this case, to make any addition for the extra weight of the ends of the rod, since at both these points the mass is inoperative to produce pressure on the slides, as is shown from the fact that the extreme terms of our series are both equal to zero.

It is not possible to balance this part of the momentum of the connecting-rod by a weight applied to the shaft, since the opposing force so produced would not act in the same line with that which it would be required to counteract. It is, however, of little importance that we should do so, since, in comparison with the pressure coming on the same part from the force of the steam exerted through the inclined rod, it is insignificant, and it is noticed here merely for the purpose of bringing all the acting forces before our minds. We have now found, then, that a weight equal to one-third the body of the connecting-rod (if it be one of uniform dimensions) and the whole of the extra weight at the crank-pin must be placed diametrically opposite to the crank-pin, and at an equal distance from the centre of the shaft, whatever be the inclination of the engine. This being done, we will proceed to inquire what will be the position and magnitude of the mass required to counterbalance the directly reciprocating parts, and the remaining two-thirds of the connecting-rod. Let C C, fig. 67, represent the direction of the centre line of the engine making any angle, C *b* E, with the horizontal, and A a mass equal to the weight of these parts, and exactly sufficient, therefore, if placed opposite to the crank-pin, to counterbalance their momentum in the direction *c c*. Let us represent the weight of this mass by the length of the radius *a b*. Now, the effect of the centrifugal force of the mass A, placed as we have supposed, will be at all times neutralised in the direction parallel with the line C C, by the motion of the reciprocating parts, but will, as we have already observed, exert an influence in a direction at right angles to that line, varying in amount according to the position of A, its intensity being proportional to the sine of the angle by which A is removed from the centre line. Its maximum effect, therefore, will be when this angle is 90°, or when the weight is at *c*. We may resolve this force into two components, *b d*

Fig. 67.



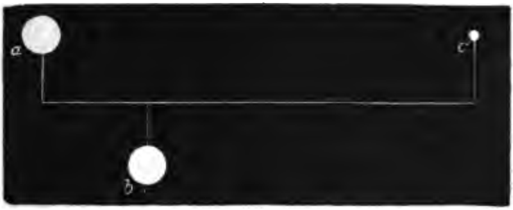
and *c d*, the one horizontal and the other vertical, and equal respectively to the sine and cosine of the angle which the centre line of the engine makes with the horizontal, and we now wish to neutralise this horizontal component.

Draw the radius *b e* in a vertical direction when the mass, A, is on the centre line. Now, if we place at the extremity of the radius a mass, B, equal to *b d*, we shall have a horizontal effect produced by it when A is on the centre line; but when A is at right angles to that line, B will be in a horizontal direction from the centre of the shaft, and will accordingly exert a force directly opposed and exactly equal to the horizontal component, *b d*, of the centrifugal force of A, and we should accordingly have the momentum of all the parts perfectly counterbalanced in that direction.

It now remains to combine the three weights which we have successively found necessary, and to find the position and magnitude of a single mass that shall exactly perform the duty of the three. To do this, lay off on the centre line the distance *b h*, equal to the combined weight of A, and the mass that we first found for counterbalancing the swing of the connecting-rod ; on *b e* lay off a distance, *b f*, equal to the mass B, and complete the parallelogram *b f g h*. The diagonal, *b g*, will represent the direction and magnitude of the resulting weight. Were it not for the effect of the weight necessary to counteract the change of momentum of the connecting-rod at right angles to the centre line, the position of this final weight would always be in a horizontal direction from the shaft when the engine was on centre, since the line *h g*, equal to the sine of the angle of inclination, would then fall from the point *a*, situated on the circle ; as it is, the required direction will always be somewhat nearer to the centre line.

We have thus far supposed the counterweight to act in the same plane in which the reciprocating parts move. But as the weight itself cannot be placed exactly in that plane we must see how we can dispose it so as to produce the same effect as if so placed. If it is a crank-shaft engine, we can easily accomplish this by dividing the counterweight into two equal parts, and placing one on each side of the crank, equidistant along the shaft from the centre line of the engine; or if, for particular reasons, this is not practicable, then we must divide the weight into portions inversely proportional to the distance from the centre line, at which we are obliged to locate them. In the case of an overhung crank, we must proceed in a different yet similar manner. It will be necessary, in order to avoid the tendency to produce rotation that exists in the case of *two* opposite forces not acting in the same line, to provide a third force, and this we may do by placing a weight exactly opposed in the direction to the counterweight, on the opposite side of the latter, from the centre line of the engine, and of a magnitude, as compared with that which we have already assigned to the counterweight, inversely as the ratio which its distance from the position of the counterweight bears to that of the counterweight from the centre line measuring along the shaft, and the counterbalance weight must now be augmented by an amount equal to this second weight. The case of a double-cylinder engine differs in no respect from those which we have already considered, since each set of reciprocating parts is to be balanced separately, and the weights may then be combined in the manner already illustrated."—*Mr. Frederick J. Slade in the Journal of the Franklin Institute.*

Fig. 68.



42. *The Practical Advantages of Superheating Steam.*—"'Superheated' steam, or steam which has received an increase of temperature without increase of weight, by the direct application of heat, has enemies who stoutly maintain that no benefit can be derived from the superheating, as the steam has its maximum efficiency as soon as generated.

The fallacy of such statements is evident on reflection, and plainly shows that those advancing and upholding them have neither practical acquaintance with the subject, nor have given it serious thought. It is clear that as the greater part of the steam generated in boilers is obliged to pass through the water above it, on its way to the steampipe, it must unavoidably carry with it much water in the form of spray, *mechanically* combined, and held in suspension. When boilers '*foam*,' this operation is generally increased by unnatural causes, the delivery of spray becoming so great as to seriously inconvenience the engine, and endanger *its* safety, as well as that of the boiler. And in boilers properly constructed and carefully operated, which may be supposed to work dry steam, *much more* water than is generally conceived is constantly carried over with the steam, and this defect cannot be *entirely* remedied, even by the most judicious arrangement of 'dry pipes,' steam drums, &c. What then becomes of this water mixed with the steam, and which has been heated at the expense of the fuel? It is evident that it is useless for *power*, and, as it has no latent heat, is very unavailable for heating or drying purposes. It cannot act otherwise than as a 'clog,' causing more friction in the steam by its presence, inconveniencing the operation of the engine, and tending to condense the steam with which it is associated. Now, by superheating this wet, saturated steam, it is converted into an elastic vapour by the complete and instantaneous vaporization of its surplus moisture, while its temperature is raised sufficient to preserve it from premature condensation in passing to the cylinder, or to the heating or drying coils.

The volume and elasticity of the steam is thus increased to a wonderful extent by a very moderate degree of superheating, and its subsequent operation in the cylinder is highly satisfactory.

But another advantage in the system should not be overlooked, and that is, the expansion of the steam *as a gas*, by the heat imparted to it *after* its surplus moisture has been evaporated. Although, as is evident, the *greatest* gain must ensue from the addition of the *first few* degrees (say 50) of heat, when the expansion of the steam from its previous saturated condition is very great, yet the highest authorities agree, that after it is thoroughly dried, the steam follows the law of gases, and its volume may be doubled by the addition of 480 degrees of heat.

It is a fact proved by most accurate experiments, that the higher the degree of superheating, the greater is the economy, and if steam could be used at a temperature of 1,000 degrees, its efficiency would be *very largely* increased.

Inasmuch as it is not practicable or convenient with engines, as at present constructed, to use steam at such extreme temperatures, we are unable to realize the greatest economy of superheating, but if ordinary steam of 50 lbs. pressure, at a temperature of 301 degrees, be superheated to 400, the addition of this 99 degrees of heat will augment its volume (or pressure) more than 20 per cent., and will not render it at all injurious to the lubrication or packing.

Where this superheating is effected by the waste products of combustion, the increase referred to is all clear gain, but when acquired, as is frequently done for convenience, at the expense of the fuel, a simple calculation (omitted here for want of space) shows that *even then* the economy from the expansion as a gas is from 10 to 15 per cent., *independent* from that realized in the vaporization of its surplus moisture (as explained), and which is as much more.

Saturated steam cannot part with any of its heat without becoming condensed, and this loss by premature condensation is often a very large percentage of the total amount used. In every unit of the steam thus condensed there are lost 1,000 units of heat, which have been supplied by the fuel, but have not been utilized. Superheated steam under the same circumstances might lose all of its surplus heat, but would still exist as steam.

In England, where the practical advantages of superheated steam are more thoroughly understood, and generally acknowledged, its employment is common, and is attended with most satisfactory and economical results. The steamers of the "Peninsular and Oriental Steam Navigation Company," have used superheated steam for many years, and its directors certify that it has saved them many thousands of tons of coal.

In this country the steamers of the 'Bay Line,' running between Baltimore and Fortress Monroe, employed superheated steam, with an economy of 30 per cent. in their fuel. The steam, which was superheated by means of an arrangement of tubes in the uptake, was maintained at a temperature of 400 degrees in the cylinder, yet a subsequent inspection of its interior surface, after using this steam for several months, showed it to be as smooth and polished as a mirror.

The writer's experience in the practical application of superheated steam with stationary boilers has shown that where the steam was superheated, *by the fuel*, about 100 degrees above the temperature due to its pressure (giving a temperature of 400 degrees in the cylinder), the saving in feed-water, or *steam*, was nearly *one-third*, and the economy *in fuel* was *one quarter*, showing that from 5 to 8 per cent. of the fuel was required for superheating the steam generated by the remainder, thereby increasing its efficiency nearly one-third. With this temperature maintained in the cylinder, by a judicious arrangement of the superheating apparatus, the operation of the engine was highly satisfactory, no water being present to necessitate the opening of water-cocks, or bring undue strains upon the cylinder-heads or connexions. It is hardly necessary to add that no appreciable action could be observed upon the lubricants, packing, or working surfaces of the engine.

The *full* economy due to the use of steam expansively cannot be realized when it is employed in the saturated condition, owing to its partial condensation during expansion. As heat and power are correlative terms, steam cannot perform work without the elimination of a portion of its heat, besides that lost by radiation. This heat, corresponding to the work done, may be taken from superheated steam without destroying its efficiency; for it will still remain in the cylinder, pure and dry, to the end of the stroke. It can be confidently asserted that no *steam* engine is entitled to that name, if it employs a mixture of water and vapour, instead of the genuine article.

The objections sometimes advanced on the score of 'want of durability' in superheating apparatuses, may be entirely removed by the exercise of a proper care in their construction and application, and by the allowance of a liberal amount of heating surface, so that it is not necessary to subject the superheaters to an undue degree of heat, which would naturally tend to their destruction. These particulars faithfully complied with, it will be found that no tangible objections can be opposed to the employment of moderately superheated steam, and when such economical results obtain from its use, it seems unaccountable that it is not more generally appreciated, and that the manufacturing public still adhere to the old saturated article, wasting by it both their time and money.

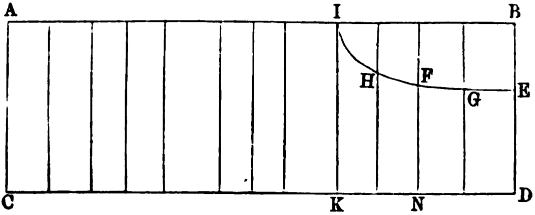
The practical advantages attending the use of superheated steam, either when used as *power* or for *heating* and *drying* purposes, are immense, and it is to be hoped that, with the increased diffusion of knowledge, the old foggy prejudices against it will be removed, while its true merits are openly and universally acknowledged."—W. H. Buckley, New York, in the "*Civil Engineer and Architect's Journal.*"

43. *Expansion of Steam.*—"An engine is working on the 'expansive' principle when the steam does not follow the piston its full distance through the cylinder, or when the steam is 'cut off' before the end of the stroke; that is, when the communication between the steam already in the cylinder and that in the boiler is closed.

It is clear that the steam in the cylinder will do some work by expansion during that part of the stroke which is uncompleted after it is cut off, and this work (which is done without any further supply from the boiler) is the saving of steam, and consequently of fuel, due to the expansion of steam.

This saving of steam and fuel is diminished to a small extent by a loss of power. For if we have a boiler carrying a certain pressure of steam, and the engine just does the work when using steam full stroke, it will be necessary to have a larger cylinder or increase the pressure in the boiler in order to do the same amount of work 'expansively,' and this will be attended with a saving of fuel in both cases on account of the expansion, and in the latter case there will be an additional saving from the fact that the greater the pressure under which the steam is produced, from a given amount of fuel, the greater the amount of work which can be developed from it. In order to illustrate this, it will be necessary to explain what work is, and the manner in which it is represented graphically. Work is the product of the resistance multiplied by the distance which it moves through. For instance, if there are ten one-pound balls to be moved the distance of one hundred feet, the total work to be done is said to be one thousand foot pounds; if they were moved one at a time, the work each time would be one hundred foot pounds, and in t times, one thousand, as before. As the area of a rectangle is the product of two factors, viz., two of its sides, it may be taken as a graphical representation of 'work' by considering one of its sides to represent the distance through which the resistance moves, and the other side to represent the amount of this resistance. In the figure let the line, A B, be the distance, and A C the resistance: then the area, A B C D, will be the work done. Hence

Fig. 69.



if we suppose A B to represent the stroke of an engine, and A C the pressure throughout the stroke, the area, A B C D, will show the work done during each stroke. If the stroke be three feet = A B, and the pressure twenty pounds, the work of each stroke will be sixty foot pounds = area, A B C D. When the steam is cut off at any point, as at I, the steam will commence to fall in pressure as represented by the lines between the curve, I E, and the line, K D. The work done by the expanded steam will be shown by the area A C D E I, the work lost, by the area I F E B, and the work saved by the area I F E D K. In order to determine these areas it will be necessary to find the average length of the lines between the lines A I E and C D.

We are enabled to do this by considering steam a perfect gas (from which there will be no appreciable error in practice if the expansion is not carried beyond limits to be mentioned hereafter), and consequently being less in pressure as the space it occupies is larger. If the stroke be three feet, as before, and the steam be cut off at I, two feet from A, the steam will occupy one and a-half times greater space at the end of the stroke than it did when it was cut off, and the pressure will be one and a-half times less, that is $20 \div 1\frac{1}{2} = 13\frac{1}{3}$ pounds = D E. At a point, F, half way between point of cutting off and end of stroke, it will occupy one and one quarter times as much space as it did before, and the pressure will be one and one quarter times less, that is, $20 \div 1\frac{1}{4} = 15$ pounds = N F. By proceeding in a similar way we find the pressure at H to be $17\frac{2}{9}$ pounds, and at G, $14\frac{6}{11}$ pounds, and at each of the points before cutting off, twenty pounds, and hence the average pressure will be $[8 \times 20 + 17\frac{2}{9} + 16 + 14\frac{6}{11} + 13\frac{1}{3}] \div 12 = 18\frac{1}{2}$ pounds, and the area A C D E I. or work done $= 18\frac{1}{2} \times 3 = 55\frac{1}{2}$ foot pounds. The area, I F E D K = work saved $= 55\frac{1}{2} - 40 = 15\frac{1}{2}$ foot pounds. The area. I F E B = work lost $= 60 - 55\frac{1}{2} = 4\frac{1}{2}$ foot pounds. From which we find that the steam, in expanding to $1\frac{1}{2}$ times its original bulk, does 37 per cent. more work than when following full stroke. The work, however, when working full stroke, was 10 per cent. more than when cutting off at two-thirds stroke, hence we must use more steam in order to do as much work as before. The additional amount of steam required will be 7·3 per cent. (and not 10 per cent., which is the amount of work required) because the steam which we add to bring up this loss of work acts expansively with that we have been considering, and therefore does 37 per cent. more work than if it followed full stroke; and 37 per cent. of 10 per cent. is 3·7 per cent. The total saving of steam working expansively one-third of the stroke, is therefore equal to the first saving of 37 per cent. less the 3·7 per cent. which must be added in order to lose no work, or nearly 30 per cent. From the above it appears that the use of high steam and a large use of the expansion principle, would be attended with great economy, and, in fact, wherever the power required is nearly uniform, as in manufactories and on smooth rivers and lakes, this principle is almost universally adopted. There are, however, cases in which it is impossible to get the full benefit of expansion.

In locomotive and propeller engines, owing to the simplicity of the machinery required to run smoothly at high speeds, it is limited to the link motion, with which it is impossible to cut off advantageously before five-eighths of the stroke has been completed. All slide-valves are limited in the extent to which they can cut off advantageously by the same cause which limits the link-motion, viz., a choking of the exhaust, causing excessive 'back pressure' or else an early release of the steam behind the piston before the stroke is completed.

The extent to which expansion can be carried economically is limited. When steam expands from a high to a low pressure, and does no work but simply enlarges its volume, it is superheated, that is, it is of a greater temperature than steam which has been produced at the lower pressure. If, however, the steam performs work in expanding, such as driving the piston of an engine, part of the steam will become liquefied, thus showing that its temperature has been lowered. This fall in temperature is not of practical importance unless the steam is expanded to more than three and a half times its original bulk, which doubles its efficiency, when it cools the surrounding cylinder to a considerable extent, and thereby condenses the steam of the next stroke until the metal is brought to its temperature, soon after which it is again cooled by the expansion of this last steam. The greater part of the water formed in the cylinder while the engine is in operation is now attributed to this condensation, and not priming or foaming, as heretofore.

From what has been said it is clear to see that steam used expansively is an economical practice, and should be so used to some extent in every case, and especially where the first cost, weight, and bulk of the machinery are of little importance compared with the fuel to be consumed."

44. *Rotary Steam Engines at the Paris Exhibition.*—"Men's minds for a number of years have been turned towards the production of an effective rotary engine, and it has been exceedingly interesting to mark the steps of progress made of late years towards this end. The first steam engine ever made was a rotary—the toy engine of Hero; and Trevithick, Hornblower, Watt, and almost all other remarkable engineers, have made attempts in this direction, and now evidently the time is coming when the rotary engine will have its reign, and its use become very general, if it will not, indeed, be universal. The great desideratum attainable in the action of the rotary engine is circular motion direct instead of the existing round-about way of first getting lineal, or more correctly, perhaps, reciprocal motion, which has then to be converted into circular motion, by means of a crank. The rudimentary steam-

engine started with direct rotary action, and the perfect steam-engine will in all probability end with it. In view, however, of the wonderful development of the powers of existing systems, we should point out some of their greatest deficiencies, and then lay down a series of requirements necessary to be fulfilled by a perfect rotary engine. In all the reciprocating systems the engine is constructed for and properly limited to one particular speed, beyond which centrifugal force and sudden change of directions are constantly accelerating their capacity for damage—the damage increasing with the rapidity of the motions in the proportion of the squares of the speed. Every part of reciprocating engines is subject to strain and injury from these sources. A connecting-rod, for example, has to be put in motion by a piston-rod, and returned, to complete the revolution of the crank by the same rod, and this rod is kept in position simply by the brasses at each end. Now, this connecting-rod will probably weigh some half a ton or more, and will work at the rate of 80 revolutions per minute; in other words, this means that the pins which secure it would each receive, in exactly opposite directions, 160 blows per minute, tending to flatten two sides of each pin and to reduce it to an oval, at the same time that the bruises tend to open the brass. Once the liberties opened, every motion gives a cannon-shot blow, which accelerates the destruction. Rapid as the Allen engine is made intentionally to run—a beautiful little engine it is—yet, when run at speeds above its proper designation, the noise from the pins of the connecting-rod at the crank and slide-block ends becomes unmistakably audible. This noise is not due to the pistons; and if a piston had true circular action there would be no noise, however high the rate of revolution. In the Allen engine this bruising action is attempted to be mitigated, and the action of the connecting-rod equalized by a beautiful system of expansion, commencing by cutting off the steam at one-fifth the stroke; but although working expansively partly ameliorates this condition, it fails to cure it. Now, we have only spoken of two parts, but the connecting-rod of an ordinary locomotive has no less than 52 distinct separate pieces, each junction or liberty of which is liable to the like damaging actions as the pins, although it may be in less degrees; but in all the same causes are ever at work, ceaselessly tending to produce misfits. Again, the primary structural arrangement of cylinder, connecting-rod, and fly-wheel, in single-acting reciprocating engines, necessitates the occupation of large amounts of space, as did, in a still greater degree, the steam engines formerly in use. If the cylinder be set vertically, with the fly above it, we have a top-heavy vibrating motion; and if we reverse this and put the cylinder high, to work downwards, we have the transmission of power in a very unfavourable position. Horizontally the arrangement would occupy a very large amount of ground area, which, in all cases, can ill be spared, and especially is an inconvenience in populous districts. If the cylinder is oscillating there is still a large amount of space occupied, and there are hot bearings and other disadvantages too numerous to detail.

The ends to be attained by a perfect rotary engine then are:— 1. Direct rotation; 2. Economy of space; 3. High speed; 4. Uniform speed of piston and perfect balance of parts; 5. Absence of exposed wearing surfaces; 6. Equality in wear; 7. Low cost; 8. Economy of consumption of steam.

Having set out with this ideal we have to compare the best of the projects put before us, and see how each fulfils most or best the required conditions.

There have recently been three notable plans of rotary engines prominently before the world—Behrens', Thomson's, and Pilliner and Hill's.

The Behrens' engine is an American invention, and, like all American inventions, very ingenious; but we do not think it the best out. It is, however, so remarkable and so simple, as compared with any reciprocating plan, that it deserves the closest criticism. The two pistons are segments of two hollow cylinders, attached by one end to two parallel shafts, and geared together so as to rotate in opposite directions at the same velocity. Both revolve in two parallel laterally communicating cylindrical bores, within an oval or bi-cylinder casing; these bores being turned from two centres, two-thirds of their diameter apart, and thus overlapping each other considerably. The two piston-shafts pass right through the case, separated from the two pistons by a cylindrical hub attached to the opposite end of the case; these two shafts are geared together by two wheels, with uniform number of teeth, so that when one rotates the other must follow at the same velocity. The form of each piston is nearly half a ring, the outer arc fitting its respective bore, and the inner one the hub. The induction and eduction pipes for the steam are arranged in opposite positions, where the two bores of the outer case meet. In the operation of the engine as a steam motor, the steam acts upon the end of the piston of each shaft alternately to blow it round, the piston not acted upon serving as an abutment to the other. The steam acts in this way upon each piston during half a revolution, continuous revolution being effected by means of the wheel gearing. The space occupied by the Behrens' engine is small, and its weight is said to be not so much as the fly-wheel and bed-plate of an ordinary engine of the same power. We have here, then, a rotary engine that will work; but which, when we come to consider its structure, is not likely to endure. In the first place, the pistons are not balanced, and the centrifugal strain of such large masses of metal whirling round at high velocities must be enormous, whilst the wear upon the axle must be uneven; the driving pulley, also, extended so far away from the pistons, must constantly strive to pull round the piston shafts, and give rise to strong one-sided strain and wear of the pistons themselves. Thus, however good the material and well fitted the parts, the mechanical construction of the Behrens' engine involves a regular decadence of action from uneven wear from the time of its starting.

The next engine requiring notice is Thomson's, of Edinburgh. This is even more difficult than the last to describe in clear terms. The two pistons, which may be said to be quarters of solid cylinders, are attached along one-half their length to equal lengths of two shafts, whose ends meet in the centre of the piston-cylinder. Each can thus work independently of the other. The shafts of the pistons are prolonged beyond the piston-cylinder at each end, and connected to each are a pair of elliptic wheels working at right angles to their major axes. The steam entry and exit are at opposite sides of the case, and the effect of the pressure and the oval wheels is to accelerate the motion of each piston alternately, so that one gains upon the other or is retarded, and thus closing up or opening the distance between them. As one piston forms the abutment to the other, the power of the engine is differential according to the variation of their velocities. The motion obtained is thus, by a series of impulses, acting alternately on the two quarters of each of the elliptic wheels, producing a bruising noise and vibration not calculated to induce a good opinion of the permanency of the engine or the correctness of its mechanical principles.

The third method recently designed is by Pilliner and Hills, of Newport, Monmouthshire, and is the most important of anything ever done in the way of a thoroughly practical rotary engine. In this apparatus there are two toothed wheels, or rather rolling curves of eight or more teeth or cogs; one of these wheels or curves is fixed on the main driving shaft, and the other, which gears into the first, is attached to another shaft. These wheels or rolling curves are equal in breadth to the whole length of the case in which they revolve. Every cog does not touch the inside of the case, but two being packed with steel packers in opposite directions, the whole revolves steam-tight. The steam is admitted into the space between the two wheels over the line where they gear into each other, and as the volume of steam increases, the cogs of the two wheels are forced apart in opposite directions. The steam escapes by a passage beneath the line of contact of the two piston-wheels. The action of this engine is most astonishing. All the parts work with perfect ease, and so little friction that a boy of nine years can blow round the piston-wheels of a 6-horse engine. All the parts, too, are perfectly balanced, and the nature of the joint made by the cogs of the two wheels with each other is such that rough castings even will wear themselves perfectly true. This engine certainly displays the greatest amount of power in the smallest amount of space with the least amount of material of any engine we have ever seen. We shall, therefore, compare it categorically with the ideal test we laid down in starting to criticise the values and capacities of rotary engines. First, then, we have in Pilliner's engine direct rotation of both pistons; and the motive power is transmitted direct from one spindle, strengthened to endure the additional work. Secondly, we have in it the greatest economy of space—a 4-horse power (indicated) Pilliner's engine working at 8 lb. of steam from boiler-power of 40 lb. to the inch, and running at 400 revolutions per minute, standing complete within a space of 18 inches by 10 inches wide and 9 inches high, and weighing but 72 lb. There are no complex parts, no frame, no connecting-rods, no cranks, no slide-valve, or any other valves, except one for starting and reversing, which latter operation is accomplished instanter from 400 revolutions to the right to 400 revolutions to the left, or *vice versa*, so quickly that the eye cannot detect the transition. Thirdly, for high speed: the 400 revolutions of which we have spoken may be increased to 1,000, or to any extent, depending only on the accuracy of the wheels, and being limited only by the quantity of steam or boiler-power. By running the engine at double speed the power is doubled also of course. Every other rotary engine is tied down to a restricted speed. Behren's at 250 revolutions, and he does not attempt to run it beyond. With high speeds beyond this one might expect to see the lumps of pistons fly out of their case; and Thomson's elliptical wheel gearing would thrash itself to pieces, and vibrate all around into destruction, with the 4,000 batters a minute that the four elliptic wheels would endure with a speed of 1,000 revolutions of the pistons. The uniform speed of piston and perfect balance of parts in the Pilliner's engine are obvious. The fifth condition of absence of exposed wearing surfaces is also fulfilled so perfectly, that the Pilliner engine might be run in a cloud of pounded emery. The sixth condition of equality of wear, is also so thoroughly fulfilled that the Pilliner engine would run true until all the material was worn away. Every engine, however perfect, must wear with use; but the test of perfection is, that none of the surfaces wear out of fit. In the Pilliner engine the wear may be around the shaft; if so, the shaft is conical, and has only to be pushed in a little way, and it will take up the wear around the original axis. If the cogs wear, the wear will be at the line of junction of the two wheels, and the pressure of the cogs upon one another produces such a wear as to keep every one with a proper outline and true surface. One of these Pilliner engines of 14-horse power has been at work for two years at the Newport works for a pair of heavy shears cutting 9-in. bars 1 in. thick, and has never shown the very slightest symptoms of any distress. The engines are set upon three points, and if the strap or any other like cause brings on any angularity of strain, the whole body of the engine moves to it, and there is no uneven wear of the internal parts, where it is of the utmost consequence there should be none. As to the seventh head, that of low cost, the price of a 4-horse power Pilliner engine is £16, and of a 6-horse power engine £24. This needs no comment. Engines can be made of any size; and the condensing principle could be most advantageously employed. As to the consumption of steam, the Pilliner engine uses no more steam than any ordinary engine of the same power; indeed, it should consume less for the same amount of work done, because there is less friction from less complication of parts, and there is no increase of steam space in proportion to the area of the pistons. The steam pressure always acts in it at right angles to the line of leverage of the teeth or cogs of the piston-wheels, and always also upon the longest line of leverage. There is no doubt whatever of the extraordinary power and marvellous compactness of these engines, and the remark of Dr. Royston Pigot, of Cambridge, is undoubtedly correct, that in an aluminium engine, supplied with petroleum oil, there would be found a concentrated lump of power that should be, if anything could be—equal to the ideal of the work required for ballooning.

The Pilliner engine bids fair to make a perfect revolution in the application of steam. The inventor has also patented a modification of his invention for a water-meter, for which purpose it is admirably suited."—*Standard*, Dec. 27th, 1867.

SECTION SECOND.—LOCOMOTIVE ENGINES.

45. *Locomotive Engines at the Paris Exhibition.*—As it is always interesting—frequently very suggestive—to know what is thought by foreigners of machinery made in countries other than their own, we give here a series of notes on the "Locomotives of the Paris Exhibition," which, under the signature of "Slade," have appeared from time to time in the pages of the "Scientific American," during the year 1867.

(*a*) *Locomotives.*—"The collection of locomotives is perhaps the most remarkable feature of the Exhibition, not only from the large number which have been sent, but from the great variety of design which exists among the different engines, some being of the most remarkable construction. Lest your readers, however, should become weary of this one department, I will refer to but one or two engines in this letter, and then pass to the consideration of some of the other objects of interest.

A tank engine from Liege, built by M. Vaissen, is exhibited in the Belgian annex. It has outside cylinders, and six coupled wheels of 4 feet 3 inches diameter, and a Bissell bogie with wheels 2 feet 7½ inches diameter. The fixed centre of the radial arm of the bogie is directly under the buffer beam, instead of back of the truck. The cylinders are placed just over the forward wheels of the bogie, and therefore are considerably inclined. The steam chests are on the top of the cylinders, and the valve gear employed is that known in Belgium as Walschaert's. Instead of the usual eccentrics, a single return crank is employed, set exactly at right angles to the main crank, and the motion obtained from this is communicated to one end of a curved link vibrating on a fixed centre, so that one end has exactly the opposite motion to the other. A radius rod works in this as in a stationary link motion, but instead of being connected directly to the valve stem, in which case, from the position of the return crank, the valve could have no lead, it is connected a few inches below this to a vertical vibrating arm, the upper end of which is attached to and supported by the valve stem, and the lower end is connected by a link to an arm projecting downward from the crosshead of the piston rod. This intermediate connexion causes the valve to be in advance or arrear of its central position when the piston is at each end of its stroke, and as the inclination of this intermediate lever will always be the same at the ends of the stroke, in whatever portion of the link the end of the radius rod may be situated, it follows that the lead of the valve will be varied by shifting the radius rod in the link. This arrangement therefore gives a variable cut-off, very similar to that of a link motion with constant lead. As the motion of the valve is in a measure controlled by that of the piston, instead of that of the crank as in the case of any eccentric valve gear, the ordinary inequality in the cut-off is to some extent avoided, though not more effectively than may be done by a properly proportioned link motion, and it has the disadvantage of a greater complexity of parts than the latter gear. It is, however, used to some extent on the Continent. The draw bar of this engine, instead of being fastened beneath the foot plate, is carried forward to a point near the forward pair of coupled wheels, and is allowed to vibrate laterally where it passes out beneath the foot plate. As it is necessary to bend this bar downward beneath the engine, the curved portion is forged in the form of a truss to give the requisite stiffness. The after pair of wheels is situated beneath the fire box, which is shallow enough to admit of this arrangement.

The English locomotives, though presenting little that is novel in design, correctly represent the excellent workmanship and simplicity of construction of the British makers. After examining the often extravagant machines of many of the continental builders, one returns with pleasure to these beautiful examples of sound mechanical ideas. The same encomium is due to the American engine also, which cannot fail to be admired for the accessibility of its parts, and the direct manner in which all the strains are transmitted and sustained."

(*b*) *Austrian Locomotives.*—"Perhaps the most remarkable part of the exhibition is the collection of locomotives that have been brought together. The design of some of these is of the most extraordinary nature, and this is especially true of the good engines from France and Austria. Beginning in the Austrian department we find a pair of engines by Sigl, of Vienna, one a goods, and the other a passenger engine. The former has eight coupled wheels 4 feet in diameter, and outside horizontal cylinders 20 inches diameter by 25 inches stroke. The piston rods are prolonged so as to pass through the forward cylinder head so as to sustain the weight of the pistons. The wheels have outside bearings of rather narrow width. The framing is formed of two plates about ¼ inch thick placed about 1½ inch apart and filled in with wood, the depth being more than two feet, but with much of the central part cut away. The cylinders, which project considerably from the frame, are bolted to the top and bottom portions of the latter, the steam-chests being placed above the cylinders. It hardly seems possible that this fastening can be sufficiently strong for cylinders of this size. The valve gear is placed outside, the eccentrics being carried by an overhung crank, and is of the straight link kind. Judging merely by eyesight measurement it is not proportioned so as to give a correct distribution of the steam. The connecting rod takes hold of the last wheel but one, and the three after wheels are connected by compensating levers, the forward one being independent. As this is situated at about the centre of the length of the slides, and therefore has the entire overhanging weight of the cylinders, it would appear that the weight on this axle must be excessive. The after axle also has the whole of the firebox overhanging it. The wheel base is 12 feet 9½ inches, which is not too long, a slight amount of end play being allowed in the forward axle. The engine is intended for wood burning and has an American chimney. The top of the boiler is slightly raised over the firebox.

The passenger engine by the same maker, has four coupled wheels and a single pair of leading wheels of a less diameter. The cylinders are placed outside, and the steam chests pass through the frames (which are quite similar to those of the goods engine) the valve gear being of the usual form of shifting link motion. There is a tolerably free access to the valves, but the cylinder fastening, as near as can be judged, is no better than in the other engine. For an exhibition where the prime object is to show the details of mechanical construction the example of one exhibitor is to be commended, who has sent an engine entirely without lagging. Many points about the engines we have been noticing are obscured by unsightly sheet iron casings. The drivings are 5 feet 3 inches in diameter, and the wheel base 13 feet 1 inch, the three axles being placed at nearly equal intervals of 6 feet 6 inches and 6 feet 7 inches. The cylinders and firebox overhang the extreme axles in this case also. The springs over the driving axle boxes are connected by equalizing levers. The boiler of this engine is made flush, and both engines have cabs, but are entirely devoid of beauty in any respect, and are just such engines as one would always expect to find dirty and neglected. They are fitted with a form of injector patented in Germany by Schan, which is of the fixed nozzle class."

(*c*) *A Noted London Locomotive.*—"Close to these engines stands the 'Steyerdorf,' an engine exhibited in 1862 at London, and constructed for working the heavy gradients on the South Austrian railway. It has ten coupled wheels driven by a single pair of outside cylinders, but the peculiar feature about it is that the two after pairs of wheels are arranged so as to swivel on a fixed centre in order to avoid the evils of a long wheel base. To permit the use of coupling rods with this arrangement an interprimary structural arrangement of cylinder, connecting-rod, and fly-wheel, in single-acting reciprocating engines, necessitates the occupation of large amounts of space, as did, in a still greater degree, the steam engines formerly in use. If the cylinder be set vertically, with the fly above it, we have a top-heavy vibrating motion; and if we reverse this and put the cylinder high, to work downwards, we have the transmission of power in a very unfavourable position. Horizontally the arrangement would occupy a very large amount of ground area, which, in all cases, can ill be spared, and especially is an inconvenience in populous districts. If the cylinder is oscillating there is still a large amount of space occupied, and there are hot bearings and other disadvantages too numerous to detail.

The ends to be attained by a perfect rotary engine then are:—1. Direct rotation; 2. Economy of space; 3. High speed; 4. Uniform speed of piston and perfect balance of parts; 5. Absence of exposed wearing surfaces; 6. Equality in wear; 7. Low cost; 8. Economy of consumption of steam.

Having set out with this ideal we have to compare the best of the projects put before us, and see how each fulfils most or best the required conditions.

There have recently been three notable plans of rotary engines prominently before the world—Behrens', Thomson's, and Pilliner and Hill's.

The Behrens' engine is an American invention, and, like all American inventions, very ingenious; but we do not think it the best out. It is, however, so remarkable and so simple, as compared with any reciprocating plan, that it deserves the closest criticism. The two pistons are segments of two hollow cylinders, attached by one end to two parallel shafts, and geared together so as to rotate in opposite directions at the same velocity. Both revolve in two parallel laterally communicating cylindrical bores, within an oval or bi-cylinder casing; these bores being turned from two centres, two-thirds of their diameter apart, and thus overlapping each other considerably. The two piston-shafts pass right through the case, separated from the two pistons by a cylindrical hub attached to the opposite end of the case; these two fts are geared together by two wheels, with uniform number of h, so that when one rotates the other must follow at the same velocity. The form of each piston is nearly half a ring, the outer arc fitting its respective bore, and the inner one the hub. The induction and eduction pipes for the steam are arranged in opposite positions, where the two bores of the outer case meet. In the operation of the engine as a steam motor, the steam acts upon the end of the piston of each shaft alternately to blow it round, the piston not acted upon serving as an abutment to the other. The steam acts in this way upon each piston during half a revolution, continuous revolution being effected by means of the wheel gearing. The space occupied by the Behrens' engine is small, and its weight is said to be not so much as the fly-wheel and bed-plate of an ordinary engine of the same power. We have here, then, a rotary engine that will work; but which, when we come to consider its structure, is not likely to endure. In the first place, the pistons are not balanced, and the centrifugal strain of such large masses of metal whirling round at high velocities must be enormous, whilst the wear upon the axle must be uneven; the driving pulley, also, extended so far away from the pistons, must constantly strive to pull round the piston shafts, and give rise to strong one-sided strain and wear of the pistons themselves. Thus, however good the material and well fitted the parts, the mechanical construction of the Behrens' engine involves a regular decadence of action from uneven wear from the time of its starting.

The next engine requiring notice is Thomson's, of Edinburgh. This is even more difficult than the last to describe in clear terms. The two pistons, which may be said to be quarters of solid cylinders, are attached along one-half their length to equal lengths of two shafts, whose ends meet in the centre of the piston-cylinder. Each can thus work independently of the other. The shafts of the pistons are prolonged beyond the piston-cylinder at each end, and connected to each are a pair of elliptic wheels working at right angles to their major axes. The steam entry and exit are at opposite sides of the case, and the effect of the pressure and the oval wheels is to accelerate the motion of each piston alternately, so that one gains upon the other or is retarded, and thus closing up or opening the distance between them. As one piston forms the abutment to the other, the power of the engine is differential according to the variation of their velocities. The motion obtained is thus, by a series of impulses, acting alternately on the two quarters of each of the elliptic wheels, producing a bruising noise and vibration not calculated to induce a good opinion of the permanency of the engine or the correctness of its mechanical principles.

The third method recently designed is by Pilliner and Hills, of Newport, Monmouthshire, and is the most important of anything ever done in the way of a thoroughly practical rotary engine. In this apparatus there are two toothed wheels, or rather rolling curves of eight or more teeth or cogs; one of these wheels or curves is fixed on the main driving shaft, and the other, which gears into the first, is attached to another shaft. These wheels or rolling curves are equal in breadth to the whole length of the case in which they revolve. Every cog does not touch the inside of the case, but two being packed with steel packers in opposite directions, the whole revolves steam-tight. The steam is admitted into the space between the two wheels over the line where they gear into each other, and as the volume of steam increases, the cogs of the two wheels are forced apart in opposite directions. The steam escapes by a passage beneath the line of contact of the two piston-wheels. The action of this engine is most astonishing. All the parts work with perfect ease, and so little friction that a boy of nine years can blow round the piston-wheels of a 6-horse engine. All the parts, too, are perfectly balanced, and the nature of the joint made by the cogs of the two wheels with each other is such that rough castings even will wear themselves perfectly true. This engine certainly displays the greatest amount of power in the smallest amount of space with the least amount of material of any engine we have ever seen. We shall, therefore, compare it categorically with the ideal test we laid down in starting to criticise the values and capacities of rotary engines. First, then, we have in Pilliner's engine direct rotation of both pistons; and the motive power is transmitted direct from one spindle, strengthened to endure the additional work. Secondly, we have in it the greatest economy of space—a 4-horse power (indicated) Pilliner's engine working at 8 lb. of steam from boiler-power of 40 lb. to the inch, and running at 400 revolutions per minute, nding complete within a space of 18 inches by 10 inches wide 9 inches high, and weighing but 72 lb. There are no complex parts, no frame, no connecting-rods, no cranks, no slide-valve, or any other valves, except one for starting and reversing, which latter operation is accomplished instanter from 400 revolutions to the right to 400 revolutions to the left, or *vice versa*, so quickly that the eye cannot detect the transition. Thirdly, for high speed: the 400 revolutions of which we have spoken may be increased to 1,000, or to any extent, depending only on the accuracy of the wheels, and being limited only by the quantity of steam or boiler-power. By running the engine at double speed the power is doubled also of course. Every other rotary engine is tied down to a restricted speed. Behren's at 250 revolutions, and he does not attempt to run it beyond. With high speeds beyond this one might expect to see the lumps of pistons fly out of their case; and Thomson's elliptical wheel gearing would thrash itself to pieces, and vibrate all around into destruction, with the 4,000 batters a minute that the four elliptic wheels would endure with a speed of 1,000 revolutions of the pistons. The uniform speed of piston and perfect balance of parts in the Pilliner's engine are obvious. The fifth condition of absence of exposed wearing surfaces is also fulfilled so perfectly, that the Pilliner engine might be run in a cloud of pounded emery. The sixth condition of equality of wear, is also so thoroughly fulfilled that the Pilliner engine would run true until all the material was worn away. Every engine, however perfect, must wear with use; but the test of perfection is, that none of the surfaces wear out of fit. In the Pilliner engine the wear may be around the shaft; if so, the shaft is conical, and has only to be pushed in a little way, and it will take up the wear around the original axis. If the cogs wear, the wear will be at the line of junction of the two wheels, and the pressure of the cogs upon one another produces such a wear as to keep every one with a proper outline and true surface. One of these Pilliner engines of 14-horse power has been at work for two years at the Newport works for a pair of heavy shears cutting 9-in. bars 1 in. thick, and has never shown the very slightest symptoms of any distress. The engines are set upon three points, and if the strap or any other like cause brings on any angularity of strain, the whole body of the engine moves to it, and there is no uneven wear of the internal parts, where it is of the utmost consequence there should be mediate shaft is placed directly above the axle of the forward pair of the four swivelling wheels, in bearings in the end of a stout link or coupling rod from the axle below it, and it thus necessarily maintains a constant distance from that axle. Another link with spherical bearings connects the bearing of the intermediate shaft with the bearing of the after pair of fixed wheels, and thus the distance between these two is maintained constant also. The intermediate shaft carries a crank at its extremities, and coupling rods extend from this to a crank on the axle below it, and in an inclined direction to the crank of the after pair of fixed axles. The connexion between the bogie frame and that of the rest of the engine is made by means of a stout pin connecting two stiff cross girders of wrought iron running horizontally between the opposite sides of the engine. The cylinders are a little over 18 inches diameter, by nearly 25 inch stroke, and the steam chests are inside between the frames. The driving wheels are fitted with steam brakes, which consist of a pair of cylinders placed vertically underneath the barrel of the boiler, the piston rods working downward and being connected by suitable levers to a shaft placed above the wheels, an arm on which carries a wooden brake block pressing on the top of the wheel. The diameter of the wheel is but 3 feet 3½ inches, and the coupling rods therefore come very near the ground. The engine weighs in working trim 4½ tons, and has a tender for carrying water only, the upper part forming an ordinary freight car."

(*d*) *Four-Cylinder Locomotive.*—" One of the most remarkable locomotives in the Exhibition is a twelve wheel coupled tank engine by Messrs. E. Gouin & Co., constructed for the Chemin de Fer du Nord. There are four cylinders of 17⅓ inches diameter, 17⅓ inches stroke, two at the forward and two at the back end of the engine, each driving three pairs of wheels, the connecting rods taking hold of the middle pair. The diameter of the wheels is 3 feet 6 inches, and the length of the wheel base is 19 feet 9 inches. To facilitate the passage of the engine around curves, two-thirds of an inch end play is allowed in the bearings of the extreme axles, and the coupling rods are provided with a joint near the central crank pin admitting of a slight horizontal movement of the extreme axle instead of one adapted to vertical motion, as usually employed. The cylinders, which are horizontal, are placed outside, and have large flanges cast on them by means of which they are bolted to the frames. The two opposite frames are connected at the same point by transverse plates, which makes a stiff support for the cylinders. The steam chests are placed on top of the cylinders so that the valves are quite accessible, and this is rendered possible by the use of an outside valve gear, instead of by the use of a rock shaft as with us. The ordinary link motion is employed. The wheels are connected by compensating levers, and the weight is very equally distributed on each pair, the total weight in working order being about 59 tons. The centre of the boiler is 7 feet 2 inches above the rails, and the fire-box is made so shallow as to clear the tops of the wheels, and is of such a width as to extend over them. This gives the large area of 33 square feet to the grates which permits the use of coal slack as fuel. Above the barrel of the boiler is placed a dryer or superheater of tubular construction, arranged as a return flue for the gases. The chimney is carried horizontally back from this to the back end of the boiler (the superheater not extending the full length of the latter) and then turns up just so as to give a vertical direction to the smoke and cinders. There are 275 tubes of 2$\frac{3}{16}$ inches diameter in the boiler giving 1,200 square feet of tube heating surface which, with 107 square feet in the fire-box and 414 square feet in the dryer and a feed water heater, gives 1,721 square feet for the total surface. The base of the chimney being near the centre of the length of the boiler the exhaust steam has a long distance to travel before reaching the blast pipe. There are a number of these engines at work on the Chemin de Fer du Nord, and they of course haul very heavy trains, but I believe they are not very steady on the rails, and it is doubtful if any more will be built. The pressure of steam used is 118 lbs.

(*e*) *Another Remarkable Engine.*—"Standing close by this is one for the Paris and Orleans railway, built at the Company's shops at Ivory. It has ten coupled wheels of 3 feet 6 inches diameter, and a pair of outside cylinders of about 19$\frac{3}{4}$ diameter by 24 inches stroke. The surface by which the cylinder is bolted to the frame plates appears ample, the latter being stiffened as in the previously mentioned engine. The most noticeable feature about this engine is that the two after axles are furnished with outside bearings, for the purpose, I presume, of removing the axle-boxes further from the fire-box, and as the bearings are maintained of an ample width on these as on the other axles, and as of course an outside crank must be employed to receive the coupling rods, an extremely long crank pin is required in the driving wheel which is the centre one of the five. This pin has three journals, the outer one of course being used for the coupling rod for the after pair of wheels with outside bearings, and the inner one is used for the coupling rod for the forward pair, the connecting rod taking hold of the middle bearing. Of course the strain of the after pair of wheels applied at such a distance from the wheel must be very severe on the crank pin. Still outside of this is an overhung crank for the eccentrics of the link motion, which is of the stationary link kind. The boiler is flush for its entire length, and is covered entirely with sheet brass as are also the cylinders. Instead, however, of this being done with taste as in our engines, it is full of corners and sharp depressions, as usual over here to adapt itself to the form of the casting, the consequence being that it can never be kept clean, and will always look badly on this account. The use of the outside link motion enables the steam chest to be placed above the cylinder, the latter being horizontal and the former inclined. The piston rods work through stuffing boxes in the front head to sustain the weight of the pistons. A long tank extends on each side of the engine just over the wheels from the cylinders to the back of the foot plate, except at a short distance from the front where a continuity is broken to allow access to the axle boxes of the forward wheels for oiling. This engine is intended for working an incline of 1 in 29."

(*f*) *Adjustment of Counterweights.*—"An engine with a steam tender, constructed at Graffenstaden for the Chemin de Fer de l'Est, is also worthy of notice. The engine has six coupled wheels of 4 feet 8 inches diameter, and the tender also six of less diameter. The bearings are outside, of good width, and the connection is therefore effected by means of overhung cranks, which, by the way, look very heavy for the size of the coupling rods employed, especially those on the axles of the tender. The cylinders for both the tender and engine are placed inside and inclined, and appear to be well fastened to the frames. The diameter of the main pair of cylinders is 16½ inches and the stroke 2 feet.

The wheel base of the engine is 12 feet 2 inches and the weight 36 tons in working order, that of the tender with 1,760 gallons of water being 26½ tons. The counterweights on the driving wheels of this engine are arranged in a manner that shows an intelligent comprehension of the action of the moving parts. In an inside cylinder engine the centre lines of the engines being situated at a considerable distance from the planes of the driving wheels, it is evident that a weight situated at either of the latter cannot counterbalance by momentum an opposite force acting in the direction of one of the former, as the tendency of two such forces would be to produce rotation around a point midway between them. By dividing the counterweight for each engine, however, and placing one portion in one wheel and the other in the one situated on the opposite side of the centre line, a perfect compensation may be effected. The weights must of course be divided in the inverse proportion of the distance of each wheel from the centre line of the engine whose parts we wish to balance. The cranks of the two engines being situated at right angles to each other, we shall have in each wheel two counterweights of unequal size, the larger placed opposite to the crank of the nearer engine and the other at right angles to this, or opposite the crank of the further engine. These two weights may of course be replaced by one occupying a position between the two, determined by the relative magnitude of the original weights, by the ordinary method of the parallelogram of forces, the size of the single weight being fixed in the same manner. It will be seen that the position given to the weights in an inside cylinder engine will be considerably removed from directly opposite the cranks, and therefore an engine having the counterweights placed in the latter position, as is generally the case, cannot be properly counterbalanced. The same considerations apply to outside cylinder engines, but as in these the plane of the wheel is very close to that of the centre line of the engine, the counterbalance of each engine may be almost perfectly effected by a weight in the nearer wheel."

(*g*) *Reversing Screw.*—"The two engines last mentioned are furnished with a screw for reversing instead of the ordinary reversing lever. This arrangement, first introduced about 4 years ago by Ramsbottom, I believe is now very generally adopted, and

I observe that most of the engines exhibited by Continental makers are provided with it. A projecting handle is in some cases applied to the hand wheel at the end of the screw, so that the wheel may be rapidly revolved in reversing. To enable the engine to be reversed in an emergency more quickly than is possible with the screw alone, the lever and screw are in some cases combined, and there are quite a number of engines in the exhibition having such a combined reversing gear varying in the details of its construction. In some, the catch of the ordinary lever is made to drop into the threads of the screw instead of into the notches of an arc, and for this purpose the screw is either made of a curved outline, large in the middle and small at the ends so that its upper surface shall correspond with the arc in which the lever moves; or the screw is fixed but at one end, and is free to vibrate as the lever moves so as to accommodate itself to its position. In others again, a divided nut is employed, which is thrown out of gear by the same means that the catch is lifted when the lever alone is used; and this is arranged to slide up or down in a groove in the lever as the latter vibrates. The latter is the form used on the express engine, exhibited by the Paris and Orleans Railway, with a few remarks on which I will conclude this letter. It has 4 coupled wheels 6 feet 7 inches diameter, and a single pair of leading wheels 4 feet 1 inch in diameter. The cylinders and firebox, as in so many engines, overhang the wheels, the total wheel base being 13 feet 2 inches. The two driving axle boxes on each side are connected by a stiff equalizing beam, and a single spring, placed at the centre of its length, transmits the weight of the engine to the wheels. The cylinders are outside, and of 17 inches diameter by 25½ inches stroke."

SECTION THIRD.—MARINE ENGINES.

46. On some of the features of the *French Marine Engines* at the Paris Exhibition, Mr. P. Burgh addressed a letter to the "Engineer," from which we take the following, referring the reader to the number of the "Engineer" for August 23d for the remainder of the remarks. From what he says at the beginning of his letter, Mr. Burgh does not agree with those who maintain that in

all departments of machinery our national ability and the power is declining,—certainly not in marine engines, about which Mr. Burgh should certainly be an authority. "As my practice," says Mr. Burgh, "embraces marine engines and boilers, I was naturally led to pay some attention to the examples exhibited. The firm of Messrs. Schneider & Co., of Creusot exhibit three-cylinder machines, with the slide-valve motion shaft driven by gearing similar in principle to the practice of Messrs. Maudslay, Sons, and Field. The Creusot example is plentifully supplied with ornamental lubricators and polished work, where painted surfaces would be as well. The arrangement of the engines evinces a want of forethought, and in many cases complication is an obligation or the result of forgetfulness. In the same shed is another example by the same makers. This is a pair of engines intended to drive one of the twin-screws of an armour plated ship belonging to the Imperial Government. This arrangement is the horizontal return action, with double piston-rods, and slipper guides. The flanges of the valve-casing are curved, and the surface on the cylinders to correspond; the eccentric rods impart a return action to the valve. The proportions of the link motion, as a whole, are not creditable, although the getting up of the job is fair. The arrangement of the hand gear is as complicated in this example as in the other, and the same want of thought evinced. What an engineer should do when designing is to see the entire matter *complete.* I do not mean every bolt and nut, but the principle of the arrangement and the locality of the details, and then set out the positions. The French engineer, in his productions, seemed to have troubled himself but little about certain matters till he came to them, and then got over the difficulty anyhow, or at least introduced complication where none should exist.

Turning from the Creusot shed, I next wended my way to the annexe on the bank of the Seine; here I found plenty to notice and a little to learn. The French Government have in motion three-cylinder engines of 950-horse power nominal collective, the steam being generated in one boiler, four shells being exhibited, and eight the complement on board. These engines and boilers are for the Imperial iron-clad ship 'Friedland,' and have been constructed at the Indret factories, and recently illustrated in your pages.

The boilers are the return tube type; each fire-box contains three sets of bars, and the total length of the grate surface is about 7 ft. 6 in.; but this dimension I may be a little wrong in, as the stoker and myself could not agree about the right of my taking dimensions. Strange to say, the gauge-glasses are at the extreme fore and aft of the boiler's front, and the facility for altering the pressure of the steam in the boiler is accomplished by a lever-weighted safety-valve. Each valve-box is at the top of the boiler, and the weight overhangs the front, a balance lever rod being arranged for relieving the pressure. Now, sir, it occurs to me that to weight a marine safety-valve with a lever is ridiculous, and a constant cause for the waste of steam when the ship rolls. The arrangement I alluded to for altering the pressure of the steam incurs also the advantage of blowing up the entire concern; an accomplishment English engineers avoid by putting the weight direct on the valve and locking the casing. I cannot see, either, the advantage of fixing the gauge pipes at the extremities of the shells; in my practice I have always found the central position to indicate more truthfully than any other. Around the uptake is the superheater, but of what type I could not learn. It appeared to me, however, to be the ordinary casing kind. The remaining features of the boilers presented nothing worthy of comment, excepting that evidently the English practice had not been totally lost sight of.

I now purpose to notice the engines of the example directly alluded to. As I said before, they are the three-cylinder type, partaking much of the Messrs. Maudslay's outline, but wanting the main desiderata which that firm is famous for producing. The French engines are on the compound system, the centre cylinder being the high-pressure, and those fore and aft the low; the latter being jacketed, the steam surrounds them before entering the centre cylinder. Now, sir, I have great and practical objections to this arrangement, which I submit are as follows:—First, the compound system is not advantageous in an economical point of view; expansion of steam is but expansion, and accomplish it however you will the principle is the same. I should like to learn the actual gain in the consumption of the steam when put first into one cylinder, or directly into three, the expansion being the same in each case. Certainly with the French engines the high-pressure steam surrounds the low-pressure, but may it not be equally certain that by so doing the steam is robbed of some of its original temperature ? My practice has taught me that the most simple means of producing a result is the better in all cases. Secondly, I contend that on account of the cylinders in these engines being of an equal area, but the steam being high and low pressure in its action, a relative unequal exertion on the centre crank results. The utility of three cranks is to attain a uniform motion, but how can this be certain when the centre crank is exposed to sudden shocks, due to the lead of the slide-valve ? and thus the evil attendant with the *single* cylinder engine is retained. Thirdly, the high-pressure cylinder not being jacketed, a certain radiation or loss of heat results ; and as high pressure steam will lose its temperature more readily than low, the omission I allude to must be a grave fault if there is a gain by jacketing.

I believe, sir, no one knows better than yourself the advantage of a short stroke for a slide-valve ; the French, however, seem to agree to differ on this point, for they have actually put single-ported slide-valves in the engines I am noticing. Fig. 1 is the French valve ; contrast this with fig. 2, which is an example by Messrs. Penn, with a single rod passing through the valve in each case. Now if a shorter stroke still be desired, take Messrs. Maudslay's type of valve as illustrated by fig. 3, being a three-ported slide purposely employed by that firm for three-cylinder expansive engines. When the Messrs. Maudslay locate their valve at the side of the cylinder, they arrange the affair as in fig. 4 ; and as I have shown their rotative expansion valve also, their relative positions can be easily understood.

The motion for the slide-valves in the French engines I am now alluding to is attained by a cranked weigh shaft, the valve-rod being guided by a slipper guide. This mode of guidance is a credit to the French engineer who introduced it, as it really is correct in principle, and therefore certain of success in practice. It is almost needless for me to inform your readers that each valve (fig. 1) being single-ported, requires a great deal of power to move it, and as it is not in equilibrium the evil is increased. So far is this certain that the weight shaft imparting the motion to the three slide valves is about 8 in. in diameter, the breaking torsion strain of which is 603,180 lb., or equal to a crank shaft for an ordinary pair of engines about 160-horse power collectively. The shaft in question is driven by a pair of spur wheels of equal diameter, one being on the engine shaft and the other on the weigh shaft at the forward ends. Reversing, stopping, and starting is effected by gearing on the end of the weigh shaft; outside the spur wheel is a pinion, and beyond this a hand-wheel with a rim; in the body of the spur wheel is a space and rack whose radii is taken at the centre of the shaft; in gear with the rack is a pinion on which shaft is a second of a larger diameter in gear with the pinion, on the shaft. Now, on turning the hand-wheel, the motion imparted to the weigh shaft will be independent of the prime mover, and thus the slides are shifted in the required direction. Happy French engineer! He saw but one point to be gained, and that was to 'shift the valve by hand,' but he forgot that, when his jam or stop-wheel outside the hand-wheel was screwed up to its work, the hand wheel would be in motion. Now, sir, fancy the difficulty of stopping suddenly with this arrangement. If the hand-wheel could not be released when the operator grasped it, simultaneously he would find himself on his back or the subject of some worse disaster; and yet the English engineer is exhorted to 'mind what he is about, for the French engineer is making *such* progress.' If simplicity of arrangement for starting gear be required, look at Messrs. Penn's starting gear, fitted by them to their engines in H.M.A.S. "Northumberland.' The 'starting wheel' is *not* in continuous motion, neither is there the chance of being hurled from your duty when starting the engines. Notice also the arrangement of the expansion gear; not one detail is introduced but what is requisite."

47. *On the Three-Cylindered French Marine Engine at the Paris Exhibition.*—The following from "Engineering," May 17th, will be read with interest on this subject:—

"The mere fact that the engineers of the French Admiralty have abandoned two or four cylinder engines, and have adopted as the standard for their large marine engines three cylinders of equal size, driving three cranks of equal radius, is sufficient to entitle the subject of their choice to our grave consideration. When we add to this the circumstance that, after ample experience of this class of engine, they have proceeded from the smaller scale to construct their largest upon the same plan, we must infer that the practical results they have already obtained have been such as to justify this revolution in their system of construction. When we further consider that not only the talents of the corps of highly accomplished and educated Ingénieurs de la Marine have applied their science and skill to investigate its theory and determine its details, but also that the best manufacturing establishments employed by the Admiralty have constructed similar engines, we must feel satisfied that there is much more in this kind of engine that should recommend it to our careful and patient investigation than the bare fact of using a three-cylinder engine would at first sight appear to require.

There certainly is much more in this engine than meets the eye, and, in order thoroughly to appreciate it, and measure its future importance, it is necessary to follow its peculiarities with patient detail right through the whole of the methods adopted for its application. Granting, therefore, that they were wise in adopting three cylinders and three cranks for the new standard marine engine, the question next arises, whether they were wise to adopt it with Woolf's principle, employing the simple high-pressure in one of the cylinders and the expansion and condensation in the two others.

There are obvious difficulties in the way of doing this with three cylinders, which do not apply when it is done with two or four. If two cylinders are used, the condensing-cylinder is ready at the top or bottom of the stroke to receive its charge of steam from the other, which has just completed its stroke; but with three cylinders driving three cranks at 120° apart, no one of the three is at the end of its stroke or at the beginning coincident with the others, therefore the usual system cannot be applied, and new difficulties stand in the way.

One characteristic feature of the engine renders this difficulty still greater. All the cylinders are *identical*—pistons, cylinders, cranks, valves, and valve gear. Although this gives symmetry and simplicity to the engine, it is hard to see why it was necessary and how it should work well, seeing the duties and nature of the high-pressure and low-pressure engines are so different; but it is quite plain that this simplicity of construction is of high value, and if it be attended with uniformity of pressure and in all three cylinders, it must be reckoned an important practical quality.

The working of the steam in the engines is as follows: No. 1 cylinder has the high-pressure steam admitted to it from the boiler at the commencement of the stroke, and it is cut off by an ordinary slice-valve when the crank has made one-third of a revolution. At this point No. 2 condensing-cylinder opens its valve, and admits steam from No. 1, where it is now expanding under the closed steam-valve. No. 2 and No. 1 continue to divide this first charge of steam until No. 2 has made one-third of a revolution; then its valve closes, and under its closed valve the charge of steam is left to expand. No. 3 cylinder opens its valve as No. 2 closes, and receives from No. 1 all the steam it can deliver during the last one-third of a revolution, at the end of which time No. 1 is completely empty, and ready to receive another charge of steam.

Now any one who follows this process carefully will see that it has difficulties and seeming inconsistencies. No. 1 is expanding its first charge while it first feeds No. 2; but it is on its way back and condensing the steam, instead of expanding it, when it makes the return stroke. Luckily, No. 2 piston is at this moment going so much faster than No. 1, that it not only takes up what No. 1 throws out, but makes room for much more, and thus, to a great extent, equalises the expansion. At this point No. 3 opens and admits steam behind the piston, the first and third pistons passing through equal portions of their cylinders during that time, though with varying velocity.

The engineer who will take the trouble to follow the steam through every portion of these phases in its revolution will see that there are several singular points to be noticed in the continually varying pressure of the steam. If he supposes that there are no vacant places at the end of the stroke, no room in the valve passages, and no space between the adjacent cylinders, he will get curious cusps in any curve by which he may represent the varying pressure of the steam as the pistons move with varying velocity at the different parts of their respective strokes. But all these are softened and rounded down in practice by the expansion of the steam into the vacant places to which we refer, and out of the aggregate there comes a moving force of surprising uniformity.

Up to this point we have only taken one side of the three cylinders; the other side of No. 1 goes through a repetition of exactly the same process; but the other sides of No. 2 and No. 3 are undergoing exhaustion into the condensers, while their opposite sides are having steam measured out into them by No. 1.

If all this has been made intelligible without a diagram, it will be apparent that this is a practicable combination of three equal cylinders into a Woolf's engine; but it will be by no means obvious that the work done in each of the three cylinders is equal —it may be unequal to almost any degree. Nevertheless, it has been so contrived in this engine, that when it is at its highest strain, during extreme work, the quantity of work done in all the cylinders is almost exactly identical.

The equality of the work done in each of the three cylinders may be pretty easily recognised, if we begin by supposing three atmospheres, of pressuse of, say 14 lb. an inch, or say 28 lb. pressure above the atmosphere, calling the vacuum also 14 lb. The total 42 lb. of steam enter cylinder No. 1, are cut off and expanded in cylinders Nos. 2 and 3, down to 21 lb., or half the original pressure; this 21 lb. is 7 lb. above the atmosphere, leaving 14 lb. to be made up by the vacuum. Thus there are 21 lb. effective in the high-pressure cylinder, and 21 lb. effective also in the low-pressure cylinders, both cutting off alike. This statement is not exact, but conveys a fair idea of the practical equality exhibited between the diagrams of actual performance of the high-pressure and low-pressure cylinders.

To render the performance of both kinds of cylinders perfectly uniform, some further refinements may yet be introduced; that such refinements will be worth the cost of additional complexity is far from certain. Some deviations from the exact angles of 120° might soften some irregularities, but might also introduce others; some variations in the degree of cut-off might possibly improve the economy of performance; possibly such improvements may be in the way of accomplishment. In the present engines some such changes are on trial.

But on the whole, it is an important fact that here are three identical engines working combined on Woolf's system on three cranks, with a very fair uniformity of pressure on all the pistons through the greater part of the stroke. What the designers consider th have achieved is the absence of those high initial pressures which a couple of large cylinders working with the same high pressure of steam, and expanding to the same degree, would have thrown on piston-rods, cranks, and all rubbing surfaces. They boast that they have much larger bearings, cool journals, and unstrained mechanism; that, in short, they have the quality of endurance and continuity of work in a high and practical degree.

There is another refinement on which they pride themselves: they superheat the steam, but they do not throw the superheated steam into the high-pressure cylinder directly. Instead of that, they throw it on to the outside of the low-pressure cylinders, and deposit the surcharge of heat in the metal of these cylinders. This done, the steam, having discharged its excess of heat, enters the high-pressure cylinder without producing the practical inconveniences of surcharged steam; and when this steam finds its way into the low-pressure cylinders, it there picks up again the surplus of caloric it had left on the outside, and thus obtains a charge of heat at the time and in the place where it is of most mechanical value. This transference of caloric to and from the steam in its different stages is ingenious, and practically works well.

It will be noticed that this three-cylinder engine requires but two condensers and two air-pumps, and they are, like the two condensing cylinders, placed at the two opposites of the engine; this leaves a large open space free in the middle of the engine for the piston-rods, slides, and connecting-rods, which are all comfortably accessible; and the centre cylinder, which has no air-pumps to work, works instead large water-pumps, to be employed in case of accident or leakage.

Another point deserves attention. The whole engine is combined into one large cellular structure of great strength, every part being made to help every other by continuous support in every direction. It should also be noticed that the eccentrics have been entirely removed from the crank-shaft in order that the greatest practicable area of the shaft should be left for the bearing surfaces, and a single subsidiary shaft with three cranks moves all the valves of the three cylinders, and is driven from the main shaft by a pair of geared wheels.

We have said enough to show that in this engine there is much to arrest attention and to reward grave consideration. From its very simple appearance there seems to be far less in it than afterwards turns out to be the case; but in looking at it, it is necessary to remember that the intention and purpose of it is not the accomplishment of a *tour de force*, or the achievement of extreme speed over a measured mile of race-ground, but endurance and preservation of sound condition during prolonged effort over great distances. For this reason we have thought it well-deserving minute and lengthened description."

DIVISION FOURTH.

PRIME MOVERS OTHER THAN STEAM ENGINES.

48. *Shaw's Hot Air Engine at the Paris Exhibition.*—This engine was exhibited in a special annexe in the park, and is the invention of Mr. Philander Shaw of Philadelphia, to whose courtesy we are indebted for the drawings from which those in Plate IX. are prepared, and for the following description:—

"The production of a useful and powerful air-engine," says Mr. Shaw, "has long been a favourite problem with ingenious mechanics, who readily perceived that, if the force of air expanded by heat could be made practically available, they would obtain a moving power far more economical and less dangerous than the steam-engine, which it would supersede to a great extent. The early air-engines were worked by the air which had passed through the fire; in the more recent, the air to be heated was confined in a receiver against a part of which the fire was made. The former failed for the reason that the solid products of combustion were not excluded from the finished parts of the cylinder, or the valves protected from injury by the intense heat of the fire; the latter, from the impossibility of heating a large volume of cold air through the walls of the furnace, readily enough to impart a rapid motion to the piston without ultimately destroying the furnace. We have adopted the first system in our engine, viz., that of heating the air in the furnace. In this manner the air is heated instantaneously, and it carries with it all the heat or power produced."

Description of the Drawings in Plate IX.:—Fig. 1, sectional plan through U U, fig. 2; fig. 3, longitudinal elevation, section through V V, fig. 1; fig. 2, lateral elevation, section through W W, fig. 1. A the cylinder; B the piston; B′ the piston-trunk; B″ the piston extension; C C C diaphragm plates; D annular space surrounding B′, which serves for the air-pump; E inlet valve for cold air; F discharge valve for same; G pipe leading into the hot-air valve; H cold air chamber; I pipe from same to the auxiliary heater; K auxiliary heater; L pipe leading from the auxiliary heater to M; M pipe conducting cold air into the ash-pit and air-chamber M′ surrounding the combustion-chamber M^3; M″ damper controlling the passage of air into the furnace; N N N small apertures through which the air enters the combustion-chamber; O pipe conducting heated air from the combustion-chamber to the cylinder; P exhaust-pipe conducting expanded air from the cylinder A into the tubes of the auxiliary heater; R induction valve for hot air; S eduction valve for same; *a* fuel receiver for supplying the fire while the engine is in motion; *b* circulating passage admitting cold air round the valve seats; *c* valve admitting cold air in the chamber *c′* surrounding the piston; *d* vacuum valve; *e* furnace door; *f* ash door.

Working of the Engine.—After the fire has been kindled, and the engine sufficiently heated to expand the air, the doors are all closed, air-tight, and in a few seconds the expansion of the products of combustion, and the heating of the cold air enclosed in the furnace, will give the pressure required to start the engine by merely turning the crank over the dead centre. Supposing the piston B to commence its downward stroke, the pressure from without will open the valve E, filling the air-pump D with cold air; the return stroke of the piston B forces this supply of air through the valve F, and the pipe G into hot-air valve R and cold chamber H; from thence it passes by the pipe I to the auxiliary heater K, into the space surrounding the tubes, where it receives the heat imparted to the tubes by the exhaust air. From the auxiliary heater the air passes through the pipes L and M, the latter of which opens at one end into the ash-pit, and at the other into the air space M′ surrounding the combustion-chamber M^3, where it receives the final heating, and is then admitted by the hot-air passage O, and hot-air valve R, to the cylinder A, and, after actuating the piston, is discharged by the exhaust-valve S and the exhaust-passage P through the tubes of the auxiliary heater out of the chimney.—Fig. 4, Plate IX., is an enlarged section of valve at F, fig. 2; fig. 5 of valve at E; fig. 6, enlarged section of part *b b* S S, fig. 3, Plate IX.; fig. 7, enlarged section of valve *d;* and fig. 8 of valve *c*, fig. 2.

49. *Otto and Langen's Gas-Engine at the Paris Exhibition.*—"In this engine gas," says 'Engineering,' in an illustrated article under date May 17th, 1867, "mixed with atmospheric air is exploded as in the common forms of gas-engine. But instead of the pressure being imparted to a crank in the usual manner, there is no resistance opposed to the movement of the piston at the moment of explosion, but it is shot up in the cylinder like a shot propelled from a gun, and the vacuum produced by the explosion and also by the momentum of the piston is the moving force. The object of this arrangement is to prevent an inconvenient accumulation of heat in the cylinder. The gas used is common coal gas, and it is ignited without the aid of electricity. The consumption of gas is said to be about 30 cubic feet per horse power per hour. Water is used to maintain the coolness of the cylinder, but it does not require renewal.

The whole column, shown in the drawing, is the cylinder, which is open at top, and it carries all the other parts of the engine upon a projecting plate on its top. The octagonal basement is a jacket surrounding the lower part of the cylinder, through which there is maintained a constant circulation of water, in order to keep it cool. The two rods depending, one from one of the two eccentrics, and the other from a short lever, are connected with valves, the former being for the admission of gas into the cylinder, and the latter for regulating the supply of air necessary to effect combustion. There are two tall guide-rods on the top of the cylinder, up which a cross-head, which is attached to the top of the piston-rod, slides. The piston-rod is rectangular, with a rack all down one-side, which gears into the cog-wheel on the fly-wheel shaft. This cog-wheel runs loose on the shaft; but within it is a ratchet arrangement, by means of which it communicates motion to the fly-wheel during the down-stroke of the piston only; for as the piston moves up and down, so the wheel, which gears into the rack on the piston-rod, revolves first in one direction, then in another. Another cog-wheel, fast on the fly-wheel shaft, gives motion to the toothed-wheel on the shaft that carries the eccentrics. It is necessary that the action of the valves should be very short and sudden, and should take place at a certain point only in each stroke, to ensure which the following arrangement has been made :—The two eccentrics are connected to one another, but both run loose upon their shaft, whilst on the foremost eccentric is a pawl, moving on a pivot, but kept down in a certain position by a catch in the short lever, shown in the drawing, just above the valve-rods. At a certain point in the stroke, when the piston is near the bottom of the cylinder, a projecting cam on the piston-rod releases the pawl by depressing the lever already referred to, which immediately falls into gear with a small ratchet-wheel fixed on to the eccentric, and so carries the eccentrics round during one revolution, at the end of which, the lever having been released, it catches the pawl and detaches it from the ratchet-wheel. The other valve is worked by another cam on the piston-rod striking the short lever to which the valve-rod is attached. At the bottom of the cylinder there is an opening in the gas-valve cover, in front of which a small jet of gas is kept constantly burning. As the valve descends it receives, in a cavity cut through it, a small quantity of gas as it is entering the cylinder, and which, on being brought opposite to the burner, ignites. The valve is now rapidly drawn up until it reaches a port leading into the cylinder, through which it communicates the lighted gas to the gas contained in the cylinder. The gas and air ports are immediately closed, and the explosion that follows drives the piston up to the top of the cylinder. Immediately after the explosion a partial vacuum is formed in the lower part of the cylinder by the condensation of the exploded gas, and the atmospheric pressure upon the top of the piston through the open cylinder top drives the piston down again, and thus a succession of explosions and vacuums in the lower portion of the cylinder below the piston maintains the motion of the engine.

The engine, as working in the Exhibition, is somewhat noisy; but other arrangements of the mechanism, however, could no doubt be applied, by which this fault could be prevented, should the principle exhibit advantages in other respects."

50. *The Hugon Gas Engine.*—From an illustrated article in the "Engineer," under date March 8th, 1867, we take the following extracts. After some remarks upon a point which need not be here alluded to, the writer goes on to say:—"We turn with pleasure to the exceedingly ingenious adaptation of the explosive force of a mixture of common gas and air, as now exhibited by Mr. E. Caspar, M. Hugon's agent, in the Poultry. As most of our readers are aware, this mixture, admitted into the cylinder in the same manner as steam, is exploded by an electric spark, in the Lenoir engine, alternately above and below the piston, and the energy developed by these explosions—which are powerful, but only momentary in their effects—is stored up in the fly-wheel, purposely made much larger in proportion to the power of the machine than is required in the case of the steam engine. In M. Hugon's engine the same development of power by the explosion of gas is effected, but the objectionable and always troublesome explosion by electricity is avoided, and a simple and apparently very successful expedient is adopted in its stead. The slide-valve is enlarged, and besides having the requisite induction and eduction ports, it carries at each end a jet of gas supplied by a flexible pipe from a vulcanized India-rubber reservoir or bellows in which it is pumped up to a certain pressure.

The ends of the valve itself, we must premise, pass beyond the casing at each end, and in the portion that so emerges are the cavities containing the igniting jets, the upper of which fires the mixture above the piston, and the lower that below in its turn. Of course these jets go out at the moment of the explosion, but a transverse fixed jet is provided, corresponding with each of them, and as the motion of the eccentric, or rather cam, which works the valve brings forth the cavity containing the moveable jet which has just been extinguished, it is instantly re-lighted as it comes opposite its attendant fixed jet, which stands by, as it were, perpetually holding a candle to it. The cavity in the slide-valve contains air enough to support the combustion of the moving jet till it comes into contact with the explosive mixture at a port leading into the cylinder. That the time of making this motion after each ignition may be as short as possible, a cam is used instead of an eccentric for working this valve, and exceedingly quick motion given just at the required point of the stroke.

Another novelty which has been introduced is the injection of a very small jet of water into the cylinder at each explosion, which, by its instantaneous vaporization, abstracts heat, and also is of some use in aiding lubrication.

A separate India-rubber pump, or bellows, and reservoir is provided for each of the two supplies of gas required, viz., the explosion compound and the exploding jets; this is necessary in order to ensure a perfectly regular supply at a uniform pressure, but we regard this part of the arrangement as probably entailing considerable wear and tear. . . . .

The claims of the patentee are:—First, the employment in gas engines of one or more valves carrying burners, nozzles, or jets, whereby the ignition of the explosive gaseous compounds is effected. Secondly, the employment in gas engines of arrangements for injecting water or other fluid capable of vaporising in the manner and for the purposes described. Thirdly, the improved valves before described. Fourthly, the general arrangement and combination of the parts of the improved gas engine. Fifthly, fitting one or more burners, for igniting the working gas, on the valve which opens and closes the cylinder ports. Sixthly, the appliances for injecting water into the cylinder.

Mr. Austin, of Victoria Wharf, who has had one of these engines in use for some little time, speaks highly of its efficiency; and we must say it seems to work with great regularity. Where small powers only are required in town workshops, and any situation where it is difficult or impossible to use steam, we see no reason why this machine should not be made an advantageous substitute for manual drudgery."

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DIVISION FIFTH.

TOOLS.

51. *Machine Tools in the Exposition.—American Machine Tools.*—"The display of machine tools," writes the special cor-

respondent (Slade) of the "Scientific American," "for metal working in the Exhibition is large, and includes quite a number of considerable novelty of design. The Americans, as is so frequently the case, are able to lay claim to the greatest amount of originality in what they have brought forward, but it is not always easy to assert that their designs are decided improvements on the usual British types of machines. Messrs. Wm. Sellers and Co. have much the largest number of tools among American firms, and their tools do no little credit to our native skill. They have not unnaturally endeavoured to send tools of as unusual design as possible, and on that account they attract considerable attention. The largest tool exhibited by this firm is a planing machine, in which the bed is stationary and the upright framing moves along over the work. The vertical slides at the sides of the frame are provided with tool heads as well as the cross frame, so that two and sometimes three faces may be planed at once. The belt is carried on two fixed pulleys, and passes around the one which is attached to the frame of the machine on its way from one to the other. The position, therefore, of the moveable pulley makes no difference in the length or tension of the belt. It is easy to see the facility which a stationary bed gives for bolting on fresh pieces of work while the machine is operating on another portion of the table, thus, of course, preventing delay in setting and removing the work, and no doubt this is a very important advantage. The economy of room that is secured is also equally evident, but there are few who will not involuntarily feel that a moving frame, even though, as in this case, furnished with a good length of base, cannot be as firm as one bolted fast to the foundations, especially when the tool is working near the top of the frame, and therefore with a very considerable leverage, acting in any case on a much smaller base than that which the ordinary sliding table has, to resist jar. It may be questioned, therefore, whether the gain of time in setting work would not be overbalanced by the necessity for taking a comparatively light cut to avoid trembling. Another novelty is a planing machine of much smaller dimensions, in which the table is provided with a rack as if it were to be driven by a pinion, but instead of the latter, a coarse-threaded screw inclined at the proper angle with the centre line of the machine, according to the pitch, is substituted as t motor. The reader will observe that, from the nature of the surfaces in contact, there can only be a bearing at any one instant on a single line of the surface of either the screw or rack, and whether the power of the parts to resist would be as great as where the rubbing is extended over a much greater surface, as in the case of a screw working in a nut, or as where little rubbing at all occurs, as with the rack and pinion, is a matter on which he can form his own opinion. The driving pulleys for this planer are so placed by means of bevel gearing as to bring the bed of the machine in the same direction relatively to the line shafting as the lathes, instead of at right angles to it, as in those of the ordinary construction. An example of his bolt-cutting machine is also exhibited, and the best praise that can be given to this machine is to notice how extensively it is used in England and how it has been copied by Continental makers. A considerable number of Sellers' patent self-adjusting injectors are also exhibited. One being cut open on one side so as to display the construction and mode of operation of the instrument. Mr. Sellers also exhibits a gear-cutting machine, a self-acting steam hammer of small size, and other tools and portions of machinery, all of considerable merit. Messrs. Bement & Dougherty are also represented in the Exhibition. One of their tools is a fine horizontal boring machine, a tool well known I believe in America.

Next we find an excellent nail machine, cutting a perfect shower of nails out of a plate at one operation. The simplicity of the machine is partly due to the particular form of nail which it produces, and this, therefore, should be described first. In one direction its sides are parallel throughout, and its thickness equal to that of the plate from which it was cut. In the other it tapers from one end to the other, and then has a short bevel on each side, forming a point. This bevel, at the point, is exactly the counter part of that under the head, so that when two nails are placed point to head, they exactly fit together, and it is in this way that they are cut. This peculiarity enables the nails to be cut without any waste metal whatever except that which is produced at the first and last cut on each sheet. The machine consists of a feed table over which is placed a stout rocking lever carrying the cutters, eight or ten in number, according to the size of the machine. At each stroke of this lever it chops off one less nail than the number of cutters. The fed is so arranged that at each stroke the sheet is moved sideways and back and forth alternately the length of one nail, and the cutters are alternately bevelled in opposite directions so that the taper that is given to one side of the nail, under one cutter, shall be in the opposite direction from that which will be given to the other side by its neighbour at the next stroke. The sheets from which the nails are cut are about 20 inches wide, and may be of any convenient length within the limits of the width to which they can be rolled, the grain running across the plate so as to be lengthways in the nail. The cutters are made very strong, are planed to the proper form, and then only require grinding across the end as they wear. The only difficulty that would suggest itself at first thought would be whether the lip, which undercuts one side of the head, would not often become broken and require a large amount to be ground off to bring it again to an edge: but this, it is stated, does not occur in practice. The machine is capable of producing 5,000 lbs. of nails per day. The nails are not of a form to cause splitting, and it is stated that they are preferred by those who have used them to any other form.

Near this machine we have another, ingeniously designed for moulding matrices for stereotype plates by a process of composing, instead of setting up type for the purpose. The matrix is formed of soft, thick paper, and the impressions in it are made by steel dies moved by a cam by power coming from a foot treadle, the action of the cam being determined by touching the keys of a keyboard as in type-setting machines. The paper matrix is fed along at the proper rate after each impression to produce the words and lines. Specimens are shown of stereotype plates made in this way, and also of printing from the plates, both of which look very well.

Again, we have a neat machine for dressing the sides of type after they have come from the moulds. The types are placed in rows, and between each row a brass space; a number of rows thus making up a block of any size. Each row in succession is passed sideways between a set of inclined cutters which remove all inequalities, and the finished type are received at the other side of the cutters and re-formed into a block, the brass spac however, having been left behind. The motions of the parts of the machine are so arranged as to avoid the possibility of the rows becoming broken or the type getting displaced.

In wood-working machinery there are a few good things, but any one familiar with the subject can see that it would be easy to go into any good shop, where tools are abundant, and select a far more interesting stock than that which professes to represent the whole nation.

There is one tool, however, that is a novelty, aud well deserving of praise. It is a machine for turning banisters or other ornamental turned work. The only operation required in running it, is to start the machine once for all, and then, without stopping, put in the square sticks and let down the cutter on it; it then finishes itself and is ready for another stick. The construction is as follows:—An iron frame, sliding vertically in guards, carries an inclined finishing cutter. The vertical side of this cutter is planed to the pattern which it is desired to turn, and as it wears it is only necessary to grind the end. This cutter has a vertical direction coinciding with the frame, and as the latter descends it comes in contact with the work at one side and passes partly by it. Its inclined position causes it to commence its work at one end and continue along to the other as it descends. To prepare the way for the finishing tool two other cutters go before, the first roughing off the corners of the stick and the second travelling over the edge of a former, begins the finished pattern. These cutters are made to move along by an inclined groove in the moving vertical frame which carries the finishing cutter. The working of the tool is beautifully simple, and it turns out a well-finished piece of work. The end of the spindle is made with a central point projecting beyond the griping edges, so that the work may be caught on this without stopping until the tail stock is screwed up, when the teeth catch it and set it in motion.

A set of cask-making machines are shown for flour barrels and other dry work. The main features are not new, though the precise application of principles may be. They are of exceedingly rough workmanship.

A very neatly arranged sawing table is among the best tools. It has a fixed countershaft, for driving, placed beneath the floor.

and the belt from this passes around a frame in which are fixed two arbors, the one carrying a rip saw and the other a cross-cut. By means of a worm gearing, either of these may be turned up so as to project above the table, and when it does of course its arbor and pulley alone take the strain of the belt, the other being down below it. The table is also provided with gauge guides by which any angle may be given, either in ripping or cross-cutting, and it appears to be a tool that would be very handy in a shop.

Justice's 'dead stroke' hammer is another novelty which appears to deserve well the attention which it attracts. Its capabilities for light or heavy work are exhibited at intervals by hammering out ingots of lead and drawing them down to a small bar. Its present success at home may have no little influence in its introduction here."

Other English Tools.—"The tools in the English department are models of solidity of design and excellence of workmanship. If there is any one branch of engineering in which the English particularly excel, it is in the construction of machine tools, and no one can walk through the machinery gallery of the Exhibition without being impressed with the superior judgment evidenced in the proportions of these tools compared with those by foreign makers. Messrs. Sharp, Stewart & Co., of Manchester, send a number of substantial tools, such as lathes, shaping machines and slotting drills, which show good design and careful workmanship. There is a good driving wheel lathe with two face plates and four tool posts, two on each side of the lathe, so that a double cut may be taken on the tires of both wheels at once. Their slotting drill differs from that made in America by Messrs. Bement & Dougherty and obtained by them from Mr. Shanks in Scotland, in that but one drill is used, and the work must therefore proceed more slowly. The tool is arranged quite differently from the other referred to, the drill in this case working vertically. Then there is that admirable tool so common in England, the radial drill. It saves an immense amount of time in drilling holes in large pieces of machinery, and has the additional advantage that it may be used for boring and work for which moveable crabs such as are in use with us for similar purposes would be wholly inadequate. Why have not some of our tool makers brought it out in America?

Whitworth's Machinery.—"But if we wish to see perfection of design and execution we must pass on to the space allotted to Mr. Whitworth. Of course it is easy to praise what is already acknowledged to be of merit, but the verdict in favour of these tools is unavoidable. It seems impossible to designate a single part as either too light or too heavy, a bearing as too large or too small, or a surface as too little or too carefully scraped. Every thing that is done shows mature consideration, and no labour is wasted on unimportant parts. Among the turning lathes which he exhibits is one without any spindle at all, the work being held between two ordinary centres and rotated by a driver placed near the middle of the length of the lathe. This is a revolving drum through which the work passes, the outer edge being provided with teeth for receiving the motion of the driving pinion. Two slide rests are used, one on each side of the driver. Another interesting tool is a special one designed for planing the faces of the hexagonal shot used in Mr. Whitworth's system of ordnance. Its construction is very similar to that of an ordinary planing machine, but the sliding table is replaced by a sliding spindle to which the shot is secured, and which has six spiral grooves cut in its surface, which give it a rotary motion as it moves forward through its bearings. Three tools are used, one above and one on each side of the upright frame, and the clutch—if so it may be called—by which the shot is held, is provided with notches properly distanced so that the other faces may be brought properly under the action of the tools. A very simple planing machine with Whitworth's patent revolving tool holder, by which a cut is taken when the bed is in motion in either direction, is exhibited, and also a radial drill of the pattern turned out at these works. This is a simpler and more neatly designed tool than that by Messrs. Sharp, Stewart & Co., and is a beautiful specimen of work. The same may be said of a small foot lathe which stands beside it. In proportion as the surfaces become smaller we observe that the scraping is more carefully done, and this tool shows the highest degree of finish. The motion of the treadle, in accordance with the usual custom of these makers, is communicated to the crank shaft of the lathe by chain belts passing around pullies in the frame of the treadle. Three surface plates are also exhibited, and this may be considered the most suggestive part of the collection, as it is to this invention that Mr. Whitworth and the world owe the means to produce the accurate bearing surfaces now required in good tools.

But what can be said of tools such as we find in the Belgian department, for example, where as a substitute for scraping, the makers have disfigured the bearings of their machines with fancy patterns, such as diamonds and circles? If this must be done, let it be somewhere else than on a working face. As we might expect, tools which exhibit such a barbarism as this also show throughout the very worst design and workmanship."

52. *Foreign Machine Tools.*—From a series of excellent articles on the machinery of the Exposition which appeared from time to time in the course of the year in the *Standard* (London) newspaper, we extract the following from a paper under the various heads as given :—*

(*a*) *Belgian Tools.*—The Belgians challenge us for cheapness; we challenge them and all the world for quality. First we meet with the exhibit of Cail, Halot, and Co., the ubiquitous firm, and certainly their tools are about the roughest lot we have ever seen. Nearest to us stands a large machine for chamfering the edges of boiler plates, the plates being held down by bolts 8 inches apart, while the tool is made to travel along the edge by means of a screw. The surfacing in this article has received an ornamental development into parallel vertical lines—an arrangement that must obviously produce an undulating and not a true plane surface. Next is a small screwing machine, which has every defect that a screwing machine can have. The mottling has here taken another form of ornamentation, and the whole surface is covered with circular scratches and dotted about, in a species of quincuncial arrangement, with lozenge-shaped patches of deep tooling, amounting almost to engraving. The production of such an abominable surface in a tool is, to a mechanician's mind, a positive crime. Now comes a very bad copy of a very nice tool —a small radial pillar-drill, exhibited by P. Fairbairn and Co., of Leeds, in the London Exhibition of 1862. In this the mottling has taken another diseased form, and the cross-filing being still apparent, is further enhanced by circles of scratchings three-quarters of an inch in diameter, and evidently purposely done with a blunt rose bit, altogether producing again an inequality of surface which it must strike the least acquainted with tools, after our explanations, is anything but what a sliding surface—upon the smoothness of which the accuracy of the work done by the tool entirely depends—should be. The next article is an exact copy, both as to principles and details of parts, with nothing left out, of Sharp, Stewart, and Co.'s shaping machine of the London Exhibition of 1862; and an improved specimen of which will be found in the present British Court at Paris. In this case, not content with the quincuncial ornamentation on the bearing surfaces, these makers have become so enamoured with their fanciful decoration, that they have actually applied it to the external surface of the framework. This is so absurd that we scarcely think we shall be believed in English workshops; but here, however, are the articles, and all unbelievers may convince themselves. Two lathes now present themselves, and that they are lathes is all that can be said about them. The head-stock looks as if the pattern for it had been made of putty by no very artistic hand; the brackets are similarly unsightly in appearance. The beds have the quincuncial ornamentation, the central dots between the lozenges being fairly scored into holes. Next, a powerful slotting machine, is a direct copy as to framing of one shown in the Exhibition of 1862 by Sharp, Stewart, and Co., and is like that also in all other parts, so far as we could see, except in being single geared instead of double geared. By this means the makers have succeeded in offering a machine of longer stroke, and therefore ostensibly seeming capable of doing that heavier work for which the size of its framing and table has not been proportionally increased. This in its commercial aspect may be illustrated by taking a 9-inch machine, for example, and merely increasing its stroke to 12 inches. Doing this does not necessarily make it a practical 12-inch machine, but gives it a fictitious appearance in specification of greater capacity than it actually possesses; and from such deceptive proceedings arises a difficulty which English manufacturers have to contend with all over the Continent, and from which they especially suffer in respect to purchasers who are wanting in experience of tools—as foreigners, directors of companies, and even government officials much more frequently are than is generally suspected—and who only look at the stated capabilities without using judgment or having practical knowledge of the proper characters of tool machinery. The machine will do the length of stroke of course, but it will be wanting in strength to do the proper amount of work. It cannot cut so deep, and therefore the cuts will have to be repeated, and longer time must be taken. In this slotting machine the development of ornamental scraping has assumed, we should hope, its climax in a regular floor-cloth pattern, the quincuncial dots being placed within lattice-work lines. The surfaces that should be plain are so rasped up by this absurd caricaturing of our proper mottling that the ornamentation can be rubbed off by a pencil on paper in like manner that antiquaries rub off old brasses in churches with heel-ball. The castings are all bad, and the imperfections of workmanship and putting together so rough that we have not the heart to go into remarks which, however important in respect to the works of good makers, would in this instance probably be deemed hypercritical. . . . . M. Auguste Detombay, of Marcinelle, has sent a ponderous-looking steam hammer, standing some 20 feet high. The two standards supporting the cylinder at top, and on which V-shaped guides are bolted, are spread out into an arch towards the bottom so as to rest on four legs, and thus permitting access to the work in hand from four sides. Four round holes are pierced in each upright of the standards on both sides, weakening the structure for no other object that one can conceive but ornamentation, as any idea of its purpose being to give light is out of the question, as no one would ever want to go inside, and could not get there even now if they did. Lucien Vander Elst et Cie., of Braine le Comte, present another steam hammer. It is of small size and self-acting, with a modification of Naylor's valve gear. The castings are moulded with better care, but the five steps and hand-railing that are bolted on to the side of the framing are suspiciously suggestive of an anticipation of something frequently going wrong with the cylinder. Our engineers do not go up to their hammer cylinders once a month, and unless accidents were likely to be frequent the provision of permanent stairs for ascent seems useless.

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* The remainder of the articles, from which we quote the following, will be found in the "Standard" newspaper of date Oct. 3d, 19th, 22d, 25th. and 29th, and Nov. 8th, 1867.

MM. Fetu and De Liege further show a machine for cutting teeth of wheels in which the circular cutter is on a vertical slide. The plane surfaces are ornamented with deeply-engraved lozenges in rows. There is a grave mistake in the design of this machine —the mandril on which the wheel is put is a fixture at one end of the bed, and the tool-holder, with all its self-acting and driving apparatus, has to travel to adjust itself to the different sizes of wheels required by the manufacturer to be cut by the machine; whereas if this head-stock were fixed the mandril would have to be moved; and this carries nothing but the change wheels for dividing. This blundering has therefore caused not only more expense in the making of the machine, but will involve greater liability to deterioration in accuracy by use in the shop from the wear of the saddle in working. Another tool by this house is a large single-plate lathe, 11 feet 6 inches in diameter. It presents no peculiarities in design; but there are two points in its structure one cannot help commenting on. One of these is the excessive thinness of the face plate, which is only three inches thick; and the other that the ring on which the teeth are cast is merely screwed to it; thus neither giving nor receiving strength the one from the other, but involving the positive disadvantage of the whole motion being transmitted through the screws which hold the spur-wheel to the face-plate; the consequent weakness of the lathe for the work it has to do is distinctly shown to the eye in this very tool by the tremulous indentations—the 'jars and dithers' as the workmen call them—on its surface, which has been turned by its own operation. The weight stated is 17,000 kilos., the price 9,600 francs, or less than half of what a good machine should cost."

(*b*) *Prussian Tools.*—"The consideration of machine tools leads us off into the courts of Prussia and Saxony, the most skilful competitors we have. The richness of the German courts in 'old familiar faces' would, indeed, give us the greatest pleasure if we could be sure that the tools we recognise so frequently by their English countenances had come there by proper invitation. Throughout all the exhibits the metal and the workmanship are very far different from the Belgian—indeed, we admit frankly that a great deal of it might be, without discredit, fathered by English houses. The designs of them we need not criticise, as we should have to re-describe them all—we believe we pretty nearly correctly use that small but comprehensive adjective—when we came to the original tools in their proper place in the British section. If the Germans set up a claim for originality in machine tools, there will have to be grand battle fought over priority of inventions—a veritable Konigsgratz for the loser. The reputation of England as the first machinist in the world should not be permitted to be lowered. The Prussians and Saxons are the best of our competitors, but they do not equal England as represented by her best tool makers." . . . .

(c) *North German Tools.*—"We shall take stock briefly then, of North German machine tools, and we shall just recognise by name familiar English models. Zimmermann, of Chemnitz, and Hartmann, of Chemnitz, are the foremost of German makers. M. Zimmermann shows some wood-working machines, amongst which we remark a dove-tailing machine, in which the dove-tails are shaped by a peculiar revolving bit—a method which is now completely beaten both as to quality of work done, and completeness of finish, by the machine in the American department, recently made in England by Robinson and Sons, of Rochdale—one of the newest things in this Paris Exhibition, and one which has made a sensation. M. Zimmermann also has a wheel-cutting engine, in which the defect of an entire separation of the main parts from each other, which we commented on in the machine of Messrs. Fetu and De Liégé, in the Belgian court, is properly avoided by placing the tool and the mandril on the same bed. His planing machine, not a very large one, has no unusual feature. It is well designed on the English pattern; and is worked by rack and pinion. M. Zimmermann also exhibits a shaping-machine and a slotting-machine, both of which have a peculiar quick return motion. One half the wheel on the crank-shaft gears into a small pinion for the forward motion for giving the cut; the other half of the same wheel is, so to speak, slipped sideways, so as to avoid that small pinion, and to gear into a larger pinion which increases the speed in the return of the tool. Thus, when coming forward to do work the action is slow and powerful, but the return from the work before coming up again for a fresh cut is sharp and quick; speed being secured instead of power. This maker has other tools less noticeable. M. Hartmann, of Chemnitz, exhibits a wheel-turning lathe, having a large thin face-plate, on which the spur-wheel is only bolted and not cast with it—exactly a repetition of the error noticed in the Belgian court. The gearing of the machine is powerful enough, but the bed-plate is totally inadequate. As the face-plate is twelve inches larger in diameter than the spur-wheel, beyond which it consequently protrudes, and as it dips below the level of the bed, it would appear as if the 7 feet 6 inch face-plate had been put on for the sake of giving the denomination of the machine a higher figure, and therefore a seeming greater value. M. Hartmann shows also two of Whitworth's duplex screw-cutting lathes; also, of the same English maker's design, a monster shaping machine—the largest in the Exhibition—with two headstocks. This has found a purchaser in the French Minister of Marine. We doubt the advisability of giving to a shaping machine so long a stroke as has been here done; for with such a length of stroke, when doing its extreme work, the overhang must be so great as to make it next to impossible to ensure that no flexion—which is the primary essential for accurate work—shall occur. We think we can detect the fear of this from the fact of the maker not having planed the tables upon their own machine, which it is apparent has not been done from the tool marks upon them being longitudinal instead of transverse."

(*d*) *Swiss Tools.*—"Just giving a glance at Switzerland, we find Messrs. J. J. Reiter and Co., of Winterthur, showing a shaping-machine on Sharp's plan, embodying such alterations for the worse as almost to cause us to pass over the detection of its origin. They have also a small hand planing-machine, and a peculiarly constructed key-grooving machine.

The French exhibit as many tools as Prussia, and both exceed in number of articles Great Britain, which is represented by three makers only—Whitworth and Co., Sharp, Stewart, and Co., and Shepherd, Hill, and Co. In the French exhibits we should remark the like following of English designs, and wherever alterations are made generally for the worse; but we have not there the same source of complaint we justly have against the Germans, inasmuch as they do permit us to patent our ideas, good, bad, or indifferent, without restraint, and pay us royalties for using our inventions. For example, Messrs. Varrall, Elwell, and

Poulot, are the makers by appointment of the two patented machines we have so pointedly alluded to in our review of the Prussian Court—Sellers's screwing-machine and Sharp, Stewart, and Co.'s recessing drill. These Frenchmen rank first amongst the machine tool-makers of France, and certainly merit the high position they hold, although they are still behind our best manufacturers, and certainly not equal to either of the three English exhibitors."

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DIVISION SIXTH.

MECHANICAL APPLIANCES.

53. From the "Scientific American" we give the following Miscellaneous Notes:—

(*a*) *The Care of Belts.*—"The apprentice sometimes finds considerable difficulty in the management of belts on machinery. Experience will in time teach him, but in this, as in many other cases, experience is a costly teacher, and much can be learned by instruction. A belt to run well should be perfectly straight, with parallel edges, and of equal thickness throughout its length. The time is past when every mechanic manufactured his own belts from the side of leather. They can be bought so much superior, of belt manufacturers who make that their business, that they are cheaper than the home manufactured. No belt should have more than one butt joint. If it is advisable to put together pieces of old belts to form one, the joints should be scarfed and lapped. Old belts have usually absorbed so much oil that the ordinary belt cement—fish glue—will not unite their surfaces; then riveting or sewing should be resorted to. In riveting, the heads should be on the wearing side and the washers on the outer surface. In sewing, the awl should pierce the leather in a slanting direction, and the lacing put through so as to present but a small amount of its surface on the pulley side. In making a butt joint the lacing should not be crossed on the wearing side, only on the outer side. The too frequent use of the belt awl is reprehensible. In making a lap joint, however, the awl alone should be used, the perforations should be as small as possible; but in a butt joint avoid as much as you can the use of the awl, and have recourse to the punch. This cuts a clean hole, much less liable to tear than the puncture of the awl. Care must be taken in unlacing a belt by pulling the lacing out with the awl. The eye sight has been destroyed by plunging the awl into the eye. If a belt is to be 'taken up,' *i.e.*, shortened, the cut should be made perfectly straight across, and for this a try-square should be used. If not cut straight and the butts be brought together and sewed, the belt will be crooked, and after running a while will become permanently curved. It is important that belts should be kept clean, especially on their under surfaces, and that no accumulations of gurry should be allowed on the pulley face. If belts are neglected in this particular they are certain to become stretched and crooked. Too much oil—the lubricating oil for machinery—rots the leather and destroys the belts. Whenever they become hard they should be moistened with good neat's foot oil."

(*b*) *Handles—Their Variety and Adaptability.*—"Does any one who uses some of the multifarious tools which pertain to the manipulation of the mechanic arts—to labour in all its branches—ever note the almost infinite variety of the appendages adapted to them to fit them for effective use? The handles differ as widely as the tools themselves. Without noticing the different manner in which the tools are attached to the handles, the variety in form and structure of the handles themselves is surprising. Many of these appendages show plainly the object of their peculiarities. For instance, the scythe snath has a very crooked appearance viewed as a piece of timber, but every curve has its object. Where the handles proper are attached, it approaches a horizontal, when in use. Below the lower handle it descends at an angle, with a curvature intended to present the blade to the grass near the ground and to swing clear of the body in using. A straighter snath would compel the mower to stoop uncomfortably and add greatly to his labour.

Some handles are long, as that of the hand rake and hoe; others short, as the axe, the hammer, the mallet. But each one has its peculiarities. The handle of the carpenter's hammer is very different from that of the machinist's hammer. Those not acquainted practically with the details of the business of the carpenter and joiner and of the machinist, might not be able to distinguish, at first sight, in what that difference consisted. The carpenter's hammer is used for driving nails into a readily yielding substance. The handle is rigid; it gives a dead blow. The machinist's hammer is used on comparatively unyielding substances. If rigid it would jar and partially paralyze the muscles of the arm. For 'chipping'—cutting iron by means of a cold chisel—the blow is received on the end of a steel chisel and transmitted through it to the rigid surface of wrought or cast iron. It may be called a spring blow. Soon as the hammer face strikes the chisel head it rebounds. All good chippers understand the necessity of having the hammer handle elastic. To produce this proper elasticity and graduate it exactly to the work to be performed, the workman will sometimes spend hours in rasping, scraping and sand-papering the wood. The blacksmith's hammer, on the contrary, has a stiff, unyielding handle, although used on the same material as that of the machinist. But in this case the material is soft and malleable.

Why do the handles of the sledge and the axe so widely differ in form? The axe may be nearly as heavy as a light sledge hammer and the handles of about the same length, but in no other respect have they any similarity. The sledge handle is straight and the axe handle curved. But the sledge and axe are not only used on different substances, but in a different manner. The striker grasps his sledge, one hand at the end of the handle and the other advanced, holding each to its place while the blow is delivered. He does not change the relative positions of his hands in striking. Even in delivering a swinging blow both hands remain together at the end of the handle. But see how the wood chopper handles his axe. With one hand at the end and the other in advance he swings his axe, bringing the advanced hand, with a quick, sliding movement, back to the end hand as the axe descends. Only women, unaccustomed to the axe, use it as the striker does the sledge. Now we see the reason of the downward, inward curve of the axe handle. The curve facilitates the downward movement of the hand by making the position of that portion of the handle more perpendicular as the blow is given. It is notorious among blacksmiths that the country lad, accustomed to the use of the axe, requires practice and repeated instructions before he becomes a good striker. We recollect a laughable incident, that was nearly a serious accident, in illustration. A farmer's boy in a smith's shop was requested to aid in 'upsetting' a bar at the end, the bar being laid across the anvil and held by the forger. He gave a blow axe fashion in this unusual, horizontal manner, and missing the bar, struck the stooping blacksmith full in the forehead, instantly 'upsetting' him.

The advantage of a handle adapted to the work to be performed is exemplified in the difference between that of the modern shovel and spade, and that of the ancient mattock or a, spade of fifty years ago. This last was perfectly straight with a cross piece at the end. Being straight, the labour of pressing the blade into the soil was greater than it is with a curved handle, as the hand and foot were compelled to act in the same line. Besides, to retain the load on the spade or shovel, or to carry it, required a very strong grasp to prevent tilting. The downward curve of the shovel handle raises the point of suspension of the load, so that the centre of gravity falls below the lifting force. The wooden grain shovel with its spoon-like scoop is a case in point. The advantage of this position of the load beneath the point of suspension can be easily tested by attempting to carry a shallow pan full of water by grasping the rim and a pail filled by using the bail.

Real science is shown as much in the form and adaptability of handles as in any mechanical device; and science is necessary: for if we examine the simple tools of savage people we shall see that it is not often the handles are well adapted to the work for which the tool is designed."

(*c*) *Friction Wheels for Driving Machinery.*—"To the use of gears there are several objections. They are noisy, have considerable friction, and the cogs are liable to break. Therefore connections are preferably made by pulleys and belts, unless it is absolutely necessary that the connection between the parts and the ratios of motion should be arbitrarily exact. In changing the direction of motion 'half-twist' belts or 'turned' belts have been largely used; the first when the driver and driven occupy relatively vertical positions, and the latter when they occupy positions on the same horizontal plane. Bevel gears and crown wheels and pinions—the latter nearly obsolete—have also been used; but a recent device which works admirably is the friction wheel. These wheels may be called bevel gear blanks. They are cast in the form of bevel gears, lacking the cogs, and the face of one is turned and polished while that of the other is recessed to receive a smoothly-fitted disc of oak-tanned sole leather, which is soaked and pressed to form. The surfaces of these two wheels are brought in contact, when mutual action is the result. One wheel runs in bearings which are suspended on pivots, so that it can, by a lever or any other suitable device, be brought in contact with or receded from the other wheel.

But not always does the mechanic who uses this device understand its proper construction. Not long ago we saw in a large manufactory two of these bevel friction wheels working, the leather covering of one of which had been renewed several times, and our advice was asked. On examination we found that the driver was the solid wheel and the driven the leather covered. The work required was rather too much for the area of the faces of the wheels, and while the driver continued to revolve the driven frequently stopped. Both run at a high velocity, and the result was that the iron-faced driver revolved under pressure against one spot of the stationary driven, cutting recesses across the face of the leather and destroying its perfect circularity. The remedy was simple. The driver should be the leather covered, and not the driven. Then, if the driver continued to revolve while the driven was stationary, the wear of the leather would be uniform, while it could make but little if any impression upon the polished iron. These matters should receive attention from mechanics. Such mistakes are not in any degree creditable."

(*d*) *A Mechanical Paradox.*—"Experiments have been going on for months in England to determine the power of screw-bolts to resist a sudden longitudinal strain. In repeated trials of projectiles against targets representing the armour-plating of ships, it was found that the bolts which fastened the inner skin and outer plate, broke short off at a point just inside of the seat of the threads in the plate. Major Palliser conceived the idea of turning off the threads on the bolts between the points on the ends which engaged with the plates, thus reducing the diameter of the bolts. The result was almost incredible. It was found that bolt with a thread cut its whole length became much stronger, or had practically more tensile strength, when the thread between the head and the engaging points was turned off, than when it was left on the bolt. Not only so: a smooth ⅜-inch bolt suspended by one end and subjected to the fall of a sliding weight striking the nut at its lower extremity, broke at the second blow, while a similar bolt turned down to ¼ of an inch, except the screw end, bore ten blows and stretched ¾ inch in 2¼ inches before breaking.

The philosophy of this curious result becomes a very interesting question. The unqualified proposition that a bar of iron is stronger after losing a portion of its material than before is incredible, but when a portion of that material is nicked or cut, the conditions are materially changed. It is well-known to mechanics that if a slight nick be cut around a bar of iron or steel it can be broken at that point by comparatively little force. This is seen every day in the smith's shop in cutting up iron. Take a bar of one and a half inches diameter and cut a slight nick around it, and it may be broken by a few well-directed blows of a sledge. But if a bar much less in diameter be attempted to be broken without first nicking it, the trial will be futile. We have seen precisely the same difference exhibited in drawing bars apart by their ends.

A very little of a substance has very little strength or power of resistance, whether contained in a large mass of the same or taken by itself. Now the force applied to break a clean bar of iron distributes itself through a considerable mass which opposes a considerable resistance. But let this force be concentrated upon a hair's breadth, and that will give way as any separate hair's breadth of iron would. The formation of the nick in the surface is the means for this concentration. The forces of the blow passing through the mass, from each side, arrive at the nick, at the bottom of which they meet and unite upon an almost infinitesimal point, and the finer the point or the sharper the cut the less the surface to offer resistance. Now in the case of the screw, the threads are nearly concentric nicks, which offer fine points for concentrating the force of a blow, being the starting of a fracture. Let these nicks be turned out, so as to present a smooth surface, and the force which would have been concentrated at one point, is generally distributed over a comparatively large surface, and the reduced diameter, smooth, actually presents more resistance than the larger diameter nicked.

There are some useful lessons to be learned from these facts. One is, that a sharp V thread weakens a bolt much more than one which has a flat bottom, as the point of the thread presents so much smaller a surface for resistance than the blunt or broad bottom. Another suggestion is, that the strongest bolt of a given diameter in the screw is that in which the body under the thread is a very little larger than the shank. Again, a bolt should not be threaded further than is required for the seat of the thread; any further threading is an invitation to a fracture."

(*e*) *Lock Nuts not understood.*—"I have noticed," says "Slade," in the "Scientific American," in his notice of the *Paris Exhibition*, "one singular fact, in walking through the various departments, which I think deserves mention. It is that, apparently, none of the European exhibitors understand the action of lock nuts, and therefore how they should be arranged. In every case where any difference is made in the thickness of the two nuts the thinner one is placed outside. Now if we suppose two nuts to be jammed against each other we shall see that they will each be pressed equally against the sides of the thread in opposite directions. When any external strain, therefore, comes upon them, the inner one will be more or less relieved from pressure against the thread until, if the force be sufficient, it becomes merely a distance piece between the body bearing against it and the outer nut. Of course in such a case it does not work, and indeed as long as it bears against the side of the thread against which it was at first forced it only increases the strain on the outer nut transmitted from the pressing body. Could anything be more meaningless, therefore, than to use a thin nut for the outer one and a stout one beneath it? To my surprise almost the only engine I have observed that has these nuts rationally arranged is Mr. Corliss's, though it is certainly surprising that so simple a matter should not be better understood. In the American department generally, however, both nuts are made of the same size, probably to avoid the labour of turning down from the usual size; but this is certainly much more reasonable than to turn down a nut, then give it all the work to do, and use a thick one to keep it tight."

Referring to the above the editor remarks—"The criticism of our foreign correspondent, 'Slade,' on the prevalent English mode of arranging the lock nut, in the machines exhibited at Paris, has given rise to a discussion in the English papers. An engineer writes in opposition to placing the thick nut on the outside as a lock nut, maintaining that the inside nut is the one to bear the strain, and must therefore have the strength; while the office of the outside nut is merely to check, by its pressure or friction, the disposition of the main nut to work back under the effect of vibration.

The editor of 'Engineering' replies to this view, sustaining Mr. Slade, and explaining that an additional nut is a lock nut only when used against an elastic pressure or a varying strain, and when screwed up so tight as to take the strain off the intermediate nut, and force its thread against the thread of the bolt in an opposite direction to the strain. The pressure of the two nuts against the bolt thread in opposite directions and against each other constitutes the 'lock,' and the outside nut takes the whole strain until it has yielded sufficiently to bring the inside nut to bear outwardly upon the bolts, when the strain is brought equally upon both. It is therefore evident that the outer nut should be the stronger."

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DIVISION SEVENTH.

METALS.

54. *Metals at the Paris Exhibition of* 1867.—(*a*) *Cast Steel at the Paris Exhibition.*—Since the year 1856, when Mr. Bessemer read his celebrated paper to the British Association, describing his method of making cast steel, the manufacture has advanced to such an extent that the Paris Exhibition of 1867 contained displays, rivalling each other in excellence, from nearly every country in Europe. His original method, when supplemented by the important suggestion due to Mr. Robert Mushet (viz., to add spiegeleisen as the source of carbon and manganese), continues little altered to the present time, and the advance of the manu-

facture is rather traced in the size and quality of the manufactured articles, than in any material alteration in the process. An exception to this is notable in the Exhibition of the Rauscher company at Heft in Carinthia, whose products have all been made in *fixed* converters, charcoal alone being used in the process, and no spiegeleisen added unless in exceptional cases. A Swedish firm at the Fagersta iron works has likewise dispensed entirely with the addition of spiegeleisen, and so far as can be judged by the appearance of articles made in this way, the results must be pronounced highly satisfactory. Having thus glanced very briefly at the more striking changes in the Bessemer process, we turn now to examine in detail the exhibitions of the different countries.

England.—Owing chiefly to a want of good arrangement, which is doubtless due to the small space allotted, the British department is not so striking as our pre-eminence in the manufacture would lead us to expect; but still a close examination of the articles exhibited will satisfy all that great progress has been made. The Round Oaks ironworks, the property of the Earl of Dudley, exhibit a material called "crystalline iron," which closely resembles ordinary steel, and has been prepared by the process of steel puddling. Bars of this material possess very great tenacity; one, for example, broke at a strain of 32 tons per square inch, and another, 1½ inch square, resisted a strain of 64½ tons, and broke the cables of the testing machine.

Messrs. John Brown and Co., of the Atlas Works, Sheffield, exhibit a portion of an armour plate, 13½ inches thick, 14 feet long, by 6 feet wide, and weighing twenty tons, and similar plates made by them for the Admiralty have been found, on testing, to possess very high resisting powers. Some large Bessemer steel tubes, made by Deakin and Johnstone's patent process from punched steel blocks, and intended for cannon, have been turned on the outside, and show the homogeneous nature of the metal, and the absence of flaws. Along with these, and likewise made by Deakin and Johnstone's process, is a hollow railway axle, a number of which have been manufactured both in France and this country, and have given excellent results. The same firm uses hammered Bessemer steel for the construction of spherical shot, which are chiefly used by foreign governments. Their outward appearance shows the excellence of the metal, since they expear as left by the hammer. The largest one weighs 113 lbs., and is 20 inches in diameter. The only remaining article we have to notice is a large armour plate, 30 feet long by 3 feet 6 inches wide, and weighing a little over 11 tons. It has been planed by powerful machines made by Messrs. Sharp, Stewart and Co., and Messrs. Shanks and Co., and the planings of the full length and width are exhibited curled up in spirals.

The Cleveland District.—The extensive iron manufacture of this district is only represented by two firms. Mr. Dixon of London sends various articles made in the district, and Messrs. Stevenson, Jacques and Co., of the Acklam ironworks at Middleborough, have an interesting display. Mr. Dixon exhibits several twisted rails, and also a remarkable piece of boiler plate bent repeatedly and doubled up; the bends are all perfect, although the thickness of the plate is ¾ of an inch. The price of this plate is £10 per ton, and it is stated to resist a strain of 22 tons per square inch without fracture. These samples show the excellence of quality of the produce of this important district; and they are the more worthy of note, since the Cleveland iron was believed to be of only second-rate quality.

Some statistics of the Acklam works will be interesting as showing the extent of the manufacture. The works cover an area of 30 acres of land, and the furnaces in use are adapted for the utilization of the waste gases in heating the boilers and hot blast stoves. To feed these furnaces 5,000 tons of raw material are required every week, and the yield of pig-iron is 1,000 tons. For every ton of iron made 1¼ ton of coke and 6 cwt. of coal slack (used for roasting the ore) are employed, and this represents the entire quantity of coal used in the manufacture. Messrs. Stevenson, Jacques and Co., in addition to numerous samples of their pig-iron, show the malleable iron made from it by other firms. These samples are chiefly armour plates and boiler plates, and there is one plate made by Messrs. Pease, Hutchinson and Co., of Darlington, which has been doubled repeatedly without fracture. As the pig-iron from these works contains nearly 1½ per cent. of phosphorus, it is at present quite inapplicable for the manufacture of steel; but if this difficulty be overcome, we may expect a rapid development of the iron industry in this important seat of the manufacture.

The Bowling Iron Company have a very fine exhibition of boiler plates. A very large plate forms the background for the articles which they exhibit, and a portion of an exploded boiler, very much bent and distorted, shows the immense toughness of the material. The Company employ crucible steel for the manufacture of weldless tires, one of which they exhibit 8 feet in diameter, and near it one even larger, made from one bloom of iron; there are also shown some welded rings, intended for strengthening boiler plates. A similar exhibition of cast steel tires is made by Messrs. Taylor Brothers, Leeds, who also show a large steel spur-wheel, 4 feet in diameter, cast complete in one mass of metal.

Several English firms exhibit Bessemer steel rails, whose durability has been repeatedly proved; the only objection to their universal introduction is their present high price. One of these Bessemer rails, made by John Brown and Co. of Sheffield, was laid down near the Glasgow terminus (where the traffic amounted to about 30,000 tons every 24 hours) in June 1864, and three years later it was not half worn out. On the same line some rails have been laid for nearly six years, and are still in good order. This extreme durability must increase the demand for these rails over the iron ones formerly used, and indeed the proved superiority of cast steel over iron must make its introduction, even at its high price, more and more common wherever great durability is desirable.

France.—It was to be expected, from the difficulty of transporting large masses of metal to considerable distances, that we should find France better represented than countries at a distance, and accordingly we find three large French firms provided with separate buildings in the Park, for the exhibition of their works. These are the Companie Anonyme des Forges de Chatillon et Commentry, Messrs. Petin, Gaudet and Co., and the Creusot Company. An idea of the extent of the works of the first-mentioned Company may be formed from the fact that it employs 9,000 men, which corresponds, on an average, to nearly three times as many human beings dependent on this one work. This extensive firm chiefly exhibits iron beams of great length and thickness,—the longest is 110 feet,—also two armour plates in the rough and finished state; while, as a contrast to these thick plates, another one 10 feet long and 3 feet 3 inches wide, possesse a thickness of only $\frac{1}{80}$ of an inch. A model is also exhibited of one of the rolling machines by which plates of such varied thickness can be manufactured.

Messrs. Petin, Gaudet and Co.—This extensive firm exhibits a very varied collection of cast steel goods, and they have not neglected to show the ores from which they extract the iron, as well as the coke and coal they employ in its manufacture. They show a block of Bessemer cast steel 25 tons in weight; it has been broken into two pieces, and the fracture shows the compact quality of the metal. A very heavy cast-steel gun, weighing 16 tons, with a bore of 9¼ inches, which has been made for the Imperial navy of France, forms one of the most prominent objects in the room; it is a breech-loader, and apparently made from a central tube, over which three rings of steel have been shrunk near the breech. Bessemer steel rails (one 25 feet long), weldless tires, locomotive axles, an immense shaft for a marine engine, a large number of castings of wheels of complicated construction, and conical and spherical steel shot, are prominently displayed in this splendid collection. A collection of weldless steel barrels for small arms is also shown, and for these this firm is justly famous. Some of these are shown which have withstood testing three times as great as the French Government require for their ordinary military rifles.

The only articles remaining to be noticed are the wrought iron girders and iron plates; the former nearly approach those of the Forges de Chatillon et Commentry; the largest one is 3 feet 3½ inches in height, 31 feet 10½ inches long, and weighs 5,512 lbs. An iron plate is shown weighing 10 tons, and its dimensions are 14 feet 10 inches long, by 4 feet wide and 12 inches thick. There is also an armour plate broken through to show the grain.

As specimens of the perfection to which iron casting has arrived, the exhibition of Messrs. Dietrich and Co. is most interesting. They show a set of rings 5 feet in diameter, only $\frac{1}{16}$ inch thick and $\frac{3}{8}$ inch wide; these are exceedingly elastic, and have been prepared by casting them the required diameter, and then turning them on a lathe, by which means both the outer and inner rough surfaces are removed. Messrs. Dietrich and Co. use only charcoal-made iron and very pure ores for these purposes; they are besides manufacturers of wrought iron and Bessemer steel, and exhibit a very fine wrought-iron locomotive wheel, 9 feet 2 inches in diameter, with 22 spokes, forged in one piece; the tire for this wheel lies beside it, and is made of Bessemer steel without weld.

A large number of weldless disc wheels, forged out of one bloom, are exhibited by the Société Anonyme de la Providence, who have made considerable progress in this branch of wrought iron manufacture, but their process is not made public. A very remarkable casting is shown by M. de Lavillé. It consists of a piece of cast iron tubing, intended for a shaft, and is 13 feet 1½ inch internal diameter, 5 feet long, and the metal is 1¼ inch thick. The appearance of the surfaces is uniform and excellent, and it has been cast in one piece at the Mines de Annet, the property of M. de Lavillé.

Germany.—The prominent position assigned to the exhibition of Mr. F. Krupp's cast steel goods was proved to be well deserved by a close examination of the separate articles. The most striking object was the enormous 50 ton cast steel gun, which for size, weight, and finished appearance, has no equal in the Exhibition. Close to this was the largest steel block ever cast; it weighs 40 tons, is 56 inches in diameter at the widest part, and has been forged under M. Krupp's 50 ton hammer. To show the compactness of the material the top end is partly polished and partly rough, and in both the closeness of the grain and homogeneous appearance of the metal testify to the excellent quality of the steel. At the close of the Exhibition this block of steel will be worked into the shaft for a marine engine, similar, we presume, to one shown by Mr. Krupp in its finished state, which weighs 9¼ tons, and is furnished with two cranks at right angles to each other, forged in their present position. Mr. Krupp likewise exhibits the weldless steel tires for which he has now been long famous; these are made first from a solid block of crucible steel, which is split up and then hammered into a ring, which is finally rolled in the tire mill to any desired size. The value of these tires for railway purposes may be judged from the fact that 40,000 of them are turned out every year from Mr. Krupp's works, and of these 13,000 are sent to this country and America. The high price of steel has hitherto been the only objection to the introduction of steel rails, and this Mr. Krupp has partly overcome by the use of a second quality of steel in their manufacture; these cost about 50 per cent. more than the best iron rails, but are much more durable. There are also exhibited a pair of locomotive driving wheels cast solid, and beautifully finished; their weight, along with the shaft, is 31 tons. A weldless ring of angle-steel is also shown, rolled to a diameter of 90 inches, and weighing 438 lbs.; such rings are used with great advantage in the manufacture of boilers. Besides the great gun already mentioned, Mr. Krupp exhibits a few of the smaller guns, which he has made in large quantities, and which are nearly all breech-loaders. One of these, weighing 12¾ tons, is rifled with 32 grooves, and is 9 inches in bore. 120 rounds have already been fired from it, with charges of 40 lbs. powder and solid shot of 300 lbs., and it is still unimpaired by these trials. The extent of an establishment producing such a variety of articles as has been noticed is shown by the following statistics of the works:—The area covered by the works is 510 acres; 8,000 men are employed in the works, and 2,000 in the collieries; for last year 63,000 tons of steel were produced, 1,000 tons of coal are burned per day, there are 120 boilers, and there are 15 miles of railways, over which run 6 locomotive engines and 150 waggons.

The Bochum Company.—Great as is the exhibition of Mr. Krupp, it is perhaps excelled by that of the Bochum Company of Rhenish Prussia, which has sent to the Paris Exhibition the best steel castings ever produced. They exhibit some very large cast steel bells, all possessing a fine clear sound, which in itself may be taken as an evidence of the soundness of the casting; the largest of these weighs 15 tons, and a smaller one 9 tons. A locomotive cylinder, of complicated form, cast in one piece of steel, and of excellent quality, and a hydraulic press of 24 inches bore, and weighing 7 tons, are also shown. The most extensive branch of their business, however, consists in the manufacture of railway wheels, which are held in great esteem by engineers, and are said to be able to run 60,000 miles under an ordinary load without requiring turning. The company sell such wheels, complete with steel axle, and weighing 16½ cwt., for 30s. per pair. In order to show the facility with which they cast large masses of metal, the Company have cast for the Exhibition a string of 22 disc wheels, all connected to the same axle and cast in one mass, which weighs 18 tons. This extraordinary casting required a mould of 30 feet in depth, which was placed on end for the casting, and although the pressure of molten metal applied to the lowest disc was immensely greater than that applied to the uppermost one, there is yet no perceptible difference in the quality of these two wheels, which have been purposely turned to show the quality of the metal. Bessemer steel is used by the Bochum Company only in the manufacture of rails, and they show a heavy rail nearly 50 feet long, intended for use on the Germany lines where traffic is heavy.

(*b*) *On Iron and Steel in the Paris Exhibition.** *By Mr. Ferdinand Kohn.*—" In the discussion which followed Mr. Fernie's interesting paper on 'Iron and steel in the Paris Exhibition,' the president of this section did me the honour to address to me a question about the processes now followed in this country and abroad in manufacturing steel castings and castings of malleable iron. Considering the importance of this subject, and the great variety of such processes now in existence and in practice, I did not, at that moment, think myself sufficiently prepared to address this section, but I proposed to draw up a few notes on that subject and upon some others closely connected with it. Having done so in the short space of time afforded me, and almost entirely from memory, I do not venture to bring this communication forward in the form of a complete paper, but I present it as an addition to the valuable paper read by Mr. Fernie a few days ago.

The collection of iron and steel at the Paris Exhibition is one of the most complete and instructive representations of the present state of iron metallurgy in all its branches which could have been brought together at any one spot under any circumstances. The rapid progress which the science and practice of iron and steel manufacture have made during the last few years, and the state of transition into which the whole iron industry of the world has been placed in consequence of these great and sweeping innovations, are the natural causes which made the display of iron and steel on this occasion more than usually desirable to exhibitors and attractive to the professional visitors.

I commence with the main cause of the great industrial revolution which we now witness, an invention with which the British Association has a historical connexion, viz., the Bessemer process. The importance and extent which the Bessemer process has acquired during the eleven years of its existence I cannot better illustrate than by quoting an approximate estimate of the present rate of production of Bessemer steel and of the productive power of the existing Bessemer steel plant in the different countries. My quotation is from a report made to the Austrian Government by Professor Tunner, one of the greatest authorities on metallurgy on the Continent, and one of the jurors in the iron and steel department at the Paris Exhibition. According to Professor Tunner's estimate, there are now in England fifty-two converters in operation, capable of producing, collectively, 6,000 tons of steel per week. Prussia has 24 converters, with a capability of make equal to 1,460 tons; France, with 12 converters in operation, can produce 880 tons; in Austria, 14 vessels can turn out 650 tons; and Sweden, with 15 vessels, has a productive capability of 530 tons per week. There are two converters at Seraing, in Belgium, and two more in Italy, also one or two in Russia, making the total power of production now available for Bessemer steel making in Europe equal to about 475,000 tons per annum. To this we must add America, with at least 50,000 tons, giving a total exceeding half a million tons of steel. The actual production of this present year does not of course come up to this figure; but it is, in all probability, considerably above 200,000 tons. In this estimate we find England's power of production fully twice as great as that of the rest of the world put together, and its actual manufacture of steel follows very nearly the same proportion. English Bessemer steel is not very well represented at Paris, but that purely accidental circumstance cannot mislead the judgment of anybody who is at all acquainted with the standing of this article in the markets of the world, with the quality of steel now turned out by the Bessemer steel works of this country, and with the extent of the trade done by them. The finest specimens of Bessemer steel exhibited at Paris are those made at Neuberg Works, in Austria, and at Fagersta, in Sweden. In both these works the raw materials consist of the purest ores known in Europe. The ores are smelted with charcoal, and the liquid iron is run from the blast furnace direct into the converters;

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* Paper read before the British Association at Dundee.

no spiegeleisen is required, but simply a small quantity of liquid iron from the same furnaces is used for adding the requisite carbon after complete decarburisation of each charge. In these localities, the Bessemer process exists in that ideal form in which it was first imagined by its inventor, but which Mr. Bessemer himself has been obliged to modify in order to make it suit the inferior qualities of ore existing in this country. That he has been eminently successful in this respect may be inferred from the fact that English hematite iron is exported in large quantities to the Continent, and used by steel-makers in France and in Germany in preference to the iron made in their own respective localities. I must confine myself to these general remarks upon the Bessemer steel in the Paris Exhibition, but I have given numerous and detailed accounts of the principal exhibits in the columns of Engineering, vols. iii. and iv.

I now come to those much-admired steel castings of Rhenish Prussia which raise so much interest and curiosity, both by their extraordinary sizes and qualities, and by the secrecy and mystification which surrounds their manufacture. Prussia is a country practically without any patent laws. Inventors therefore are at war with society there, and that war manifests itself by the closed doors of all great industrial establishments, and by an amount of jealousy with regard to technical information which is entirely unknown in any other place. This explains the position of those celebrated steel-makers, like F. Krupp, the Bochum Company, and some others, who have succeeded in making important improvements in steel manufacture, and are now obliged in self-defence to protect their mental property from piracy in this barbaric manner. I have already stated it as a suggestion that the steel castings of the Bochum Works may have been produced by running into the moulds a metal which contains more carbon than steel, and is, in fact, cast iron, and by subjecting the finished casting to a subsequent process of decarbonisation. There are many other steel-makers who make use of a similar process for obtaining sound malleable castings of great strength. The process of making malleable cast iron long practised in England, consisted in surrounding the cast iron with a quantity of pure iron ore, or oxide of iron, and exposing it to a high temperature for a length of time which was proportionate to the thickness of the mass of cast iron. By this process of cementation carbon was removed from the metal, and combined with the oxygen contained in the ore. This process is necessarily imperfect, since carbon is not the only impurity contained in cast iron, and the majority of the other elements is left in the mass. It has been, therefore, found necessary to use exclusively charcoal iron made with cold blast for this process, since this material contains less impurities and a smaller percentage of silicium than coke iron.

An improvement upon this process is that now practised by Messrs. M'Haffie, Forsyth and Co., in Glasgow. This I understand to consist in melting hematite iron in a cupola with some addition, the composition of which is kept a secret. The iron, when cast, is very hard, white, and brittle, but after decarburisation it very much resembles cast steel in all its properties. According to this description of the process, I should suppose that the admixture in the cupola may principally consist of an oxide of manganese, which would deprive the iron of a part of its silicium, and thereby make it more suitable for being converted into steel by cementation. Still it remains doubtful whether any amount of admixtures will sufficiently purify the iron in the cupola for producing good steel by cementation, and the inferior tenacity of that material, to which Professor Rankine referred a few days ago, seems to be due to this cause. One of the most scientific methods of producing steel castings is that invented by M. Pierre Martin, of Sireuil, in France. M. Martin melts pig iron of a good quality, such as is used in the Bessemer process, in a Siemens furnace. He works at a very high temperature, and, by the action of a slightly oxidising flame upon the surface of the iron, succeeds in removing the silicon and other impurities from the iron, leaving only an excess of carbon in the liquid mass. This is then tapped from the furnace and cast. The castings, after being sufficiently cooled, are placed in another Siemens furnace, having a lower temperature and a flame slightly overcharged with gas. This flame effects the process of cementation in a very perfect and uniform manner, the carbon of the iron being taken up by a part of the carbonic acid contained in the flame. As the process continues, the temperature of the furnace is raised, the flame being always maintained in its neutral character to prevent oxidation of the surface of the metal by the action of free oxygen. After a certain time, which depends on the thickness of the article operated upon, the process of cementation is completed, and the casting converted into steel. M. Martin has exhibited some very fine castings of that kind at Paris, and his process attracts a great deal of attention on the part of steel-makers. Messrs. Emile and Pierre Martin have also introduced another new steel process, which is now making rapid progress in France under the name of the Martin process. This consists in melting pig iron in the Siemens furnace, as described before, and in adding to the molten mass a suitable proportion of wrought iron, steel or pure iron ore, a process patented and described long before this by several inventors, but never as yet practically and successfully carried out. The Martin process, as far as is known at present, is a practical success. It has been recently introduced in several of the largest establishments in France—the Creusot works amongst these—and it is working to satisfaction everywhere. The principal advantage of this process consists in the facility which it affords for using up old iron and converting it into steel.

I have only to mention one more new process for making steel represented in Paris. This is a recent invention made by Mr. Siemens, and consists in making steel direct from the ore in a regenerative gas furnace. Mr. Siemens has exhibited a model of his proposed furnace, and a small piece of steel made by his new process, showing that his experiments have been so far successful.

In concluding these notes I wish to make a few remarks upon that vague notion now existing in this country, that the superiority and predominance of British iron manufacture had ceased to exist, or was threatened to be overthrown in the future by Continental competition. There are certainly no indications of such a state of things in the Paris Exhibition. If we look at the elements upon which all iron industry is based, we find British coal, although rising in price, still cheaper and better than that of most other countries, we find British hematite and other ores of similar purity abundant in this country, in close proximity to the great coal districts, while the French are importing iron ores from Elba, Sardinia, and even from Africa, and the Swedes and Austrians, who have good ores, are restricted to use charcoal as their fuel. With regard to the better qualities of iron, this country has, therefore, an advantage over all other iron manufacturing localities in the first cost of materials, which cannot fail to secure its superiority for some time to come. Equally so are the districts which produce the cheapest kinds of iron capable of holding their position in the markets of the world against anything that has been produced on the Continent, or shown in this Exhibition. From the finest Styrian Bessemer steel down to the cheapest rolled iron made in the Saar district of Prussia, or in Belgian ironworks, there is nothing which can compete with British iron in the long run. Krupp's steel is the only article, perhaps, that makes an exception; but this has been so for a long time past, and it is, therefore, no more likely now to interfere with the general superiority of British iron manufactures than it did many years ago.

Having yesterday heard the very valuable and interesting report presented to this section by Dr. Fairbairn, I desire to add a few remarks with regard to some tests of iron and steel which I have noticed in the Paris Exhibition. There are many fractured steel bars of varying degrees of hardness exhibited by different parties, and in all these a striking resemblance presents itself with regard to the appearance of the lines of rupture. The fibres in tension break in a straight line, while in that portion of the bar where the fibres are compressed a wedge-shaped piece is forced out. The shape of this wedge, and the relative position of the point where its two sides meet, and which point seems to represent the neutral fibre of the bar, appears in all specimens to be strictly dependent upon the degree of hardness of the steel. The tests in which this is most prominently shown are those made by Mr. David Kirkaldy for the Fagersta Works, in Sweden; and these are all the more instructive since the exact chemical analysis—so far as contents of carbon are concerned—is given with each specimen. It is clearly visible that the point representing the neutral fibre lies nearer to the line *a b* (or top flange), in the harder specimens, and it descends towards the line *c d* (or bottom flange), in the specimens of a softer kind, until at last, in the softest specimens, the wedge disappears altogether, since they double up without fracture. This seems to indicate a varying proportion of tensile and compressive strength in steel of different degrees of hardness, which will be best illustrated by a kind of diagram. . . . Suppose the datum line, A B, to be graduated in the divisions corresponding to decreasing percentage of carbon in the steel, and the line A C to be proportionate to the tensile strength of the hardest steel, then the decrease in tensile strength with decreasing contents of carbon will be represented by a curve, C D, the law of which has, of course, not been ascertained as yet. If, further, A E represents the strength of the same hardest specimen of steel in compression, it seems from what has been observed hitherto, and also to some extent from Dr. Fairbairn's tables, that the line, E F, which represents the decrease of strength in compression in softer steel, will fall more rapidly than the first, and ultimately cross C D, so that for wrought iron, which must be supposed to be the last element of this series, the resistance to compression will be only half that which is offered to a tensile strain. The softest kinds of steel now in use seem to range somewhere about the point where the two lines cross each other, while in the hardest kinds it appears that the strength in compression may be about three times as great as that in tension. I think, therefore, that it would not be advisable for engineers to rely in all cases upon the average proportion arrived at by Dr. Fairbairn, and which is expressed in his abstract of results, viz., that the strength of steel in compression is about double its tensile strength. This proportion seems to be correct only for those kinds of steel which on the diagram represented the medium quality of the specimens tested, and might be represented by the line *m n*. With regard to some of the softest specimens of steel, which, according to Dr. Fairbairn's tables, have given the highest results, I wish to draw attention to the fact that these specimens come from two different makers, viz., Messrs. Cammell and Company, and Messrs. H. Bessemer and Company. These specimens appear to be Bessemer steel of that quality usually made for boiler plates. I can find no better proof of the scientific perfection and reliability of the Bessemer process as practised in England than the close correspondence of the results obtained with these samples. There are two different establishments having no connection with each other, entirely independent in their practical management; they both make a certain quality of steel to be used for boiler plates, and the results shown by their products under the test are so nearly alike, both in tensile and in compressive strength, as to fall almost within the limits of observation.

The President said he quite concurred with the author of the paper in his remarks on the patent laws. He instanced the reaping machine invented by Mr. Bell, which, he said, was, in consequence of no patent having been taken out for it, allowed to lie over a long time. Had Mr. Bell taken out a patent, some of the agricultural implement manufacturers would have taken to the invention, and the country would have had the benefit of its excellent qualities twenty or thirty years sooner. With regard to the diagram illustrating the relative proportions of tensile and compressive strength of different kinds of steel, he thought the curves, if continued on the other side, so as to represent iron with a greater percentage of carbon, would follow a course as indicated by the dotted lines C M and E N, and the line R N would then represent grey cast iron, the tensile strength of which is below that of wrought iron. The strength in compression would fall less rapidly, as indicated by the curve E N. This would then complete the diagram for the entire range now in existence between cast iron on one side and wrought iron, in which the percentage of carbon comes down to zero, on the other side. He concluded by stating that the idea of constructing such curves was very useful, and that in future such curves should be constructed from the data already in existence in the reports and tables."—For diagrams see "Engineering" for Sept. 27, 1867.

(*c*) *On the Iron and Steel at the Paris Exhibition.*—"At the recent meeting of the British Association at Dundee Mr. John Fernie, of Leeds, spoke on the above subject before the Mechanical Section. He remarked that much had been said about the advance of French manufacture in this department as compared with the English. But such ideas would be dispelled by taking into consideration the effect of the protective tariff of the French customs, which interfere with our exports to France, and lessens the inducement for English manufacturers to exhibit their products in Paris. Mr. Fernie stated that the protective duties apply principally to manufactured iron, while coal and pig iron enter duty free; and the British department of the Paris Exhibition contained accordingly scarcely anything but the products of some Yorkshire houses who carry on some trade with France on account of the high quality and reputation of their products. In the French department some specimens of rolled iron had attracted much attention, since they were of a section far larger than any similar girders ever rolled in this country. The largest section was a double T exhibited by the Forges of Chatillon and Commentry; and next to those came some girders made by Messrs. Petin, Gaudet, of St. Etienne. Girders of that description had been made in England before this, and used for iron-plated ships; but the mode of manufacture was different, the girders being rolled as two simple T irons, and welded together in the web. The girders now made in France, on the contrary, are rolled in one piece from a single pile. These girders were very short comparatively with their other dimensions, and their manufacture should therefore be considered as a *tour de force* rather than as a practically useful innovation. In the manufacture of such girders there was a large surface exposed, first to the action of the fire in the furnace, and then to the process of rolling, which was likely to deteriorate the iron. Consequently, even though this process was one which could be successfully adopted, there would be considerable doubt as to whether the strength of the girder made in this way would be equal to a girder made in the ordinary way—of boiler plate riveted together. These girders, in the opinion of Mr. Fernie, had been made for the purpose of going beyond the English people, and not so much for their practical value. Another novelty was the process of stamping, lately introduced, and which has been very largely carried out by the French. This process was to make a complicated forging in small pieces fixed together, putting it in the furnace, raising it to a welding heat, and then completing the whole in a pair of dies by means of a few blows from a powerful hammer. This process had not come much into use in this country; but one English house had shown several specimens quite equal in manufacture to those exhibited by the French. The manufacture of steel in large masses, exhibited by Krupp and the Bochum Company, far exceeded in size anything as yet manufactured in England. The specimens from the Bochum Company were, in the opinion of Mr. Fernie, deserving of special mention. Twenty-two railway wheels of cast-steel, all in one piece, and a still more beautiful casting of a locomotive cylinder were the finest steel castings ever exhibited. So far as France is concerned, England had not been excelled in any department in the manufacture of iron.

Professor Rankine wished to know by what process steel was manufactured at the Bochum Company.

Mr. Fernie said he believed it was by the crucible process.

Mr. Ferdinand Kohn said he had been in Paris a considerable time, and had directed his attention specially to the iron department; and having had a conversation with the manager of the Bochum Company, he could state that the Bochum steel was not manufactured by the ordinary crucible process. The mode of manufacture was a secret, but he believed that the process consisted in the casting of material containing a greater quantity of carbon than steel, and afterwards subjecting these castings to a process of decarburisation.

Mr. Fernie, in answer to a question put to him by Mr. P. Le Neve Foster, stated that the reason why an order had been given by the Great Eastern Railway Company to a French house to make forty locomotives was in consequence of the English locomotive makers having more orders than they could execute at the time. Now, however, there was an immense number of new houses, and the old firms, having added new branches to their businesses, he did not think that in future English orders would require to be given to foreign companies to execute."

(*d*) *New Modes of Making Steel.*—The Paris Exhibition is, says "Engineering," under date Aug. 23d, 1867, "particularly rich in specimens of steel obtained direct from pig iron or iron ore by certain new methods of conversion, recently invented, partly with an intention of avoiding Mr. Bessemer's patents, and partly also with an idea of removing from the iron the noxious admixtures of sulphur, phosphorus, and other elements which have proved unassailable by the Bessemer process, and by most of the other methods adopted for making steel. We have already noticed Mr. Siemens's new plan of making steel direct from the ore in a regenerative gas furnace, and we have noted other applications of the Siemens furnace to the manufacture of cast steel direct. There are two inventions of this kind in the French department, both represented by some very fine specimens of steel, made by a direct process in the Siemens furnace, and without crucibles. The two inventors, we believe, are now involved in a lawsuit for infringement of patents, although it is difficult to see how either of the two can substantiate any claims, with the exception of more or less unimportant details.

The two inventors are M. Berard, of Paris, whose operations are carried out at Montataire, and Messrs. Emile and Pierre Martin, of Paris, the well-known proprietors of the forge at Sireuil, France. M. Berard has the idea of exposing his pig iron to a protracted series of alternative decarburisations and recarburisations. He works a quantity of molten pig iron in a Siemens furnace, through which an oxidising current of heated gases, or a flame containing a surplus of air, is passed. The oxygen of the air is thus enabled to act upon the impurities contained in the iron in the same manner as it does in the Bessemer process. After continuing this action for a certain time, M. Berard reverses the process, that is, he introduces a flame which contains a surplus of gas, and is, therefore, capable of parting with some of its carbon, so as to restore it to the liquid iron. By this alternating process M. Berard believes that he is in a position to protract the process of conversion to any desired length of time, and to give the oxygen an opportunity of removing from the mass a greater quantity of impurities than can be got rid of by the Bessemer process. M. Berard makes use of the changes of current required for working the regenerators of the Siemens furnace for effecting his alternating operations. He divides the furnace into two halves, each forming a receptacle for a quantity of molten pigs, the two compartments being separated by a bridge made of fire-bricks. The flame entering the furnace at one side must pass over one mass of iron before it can reach the bridge, and after that it passes over the second charge of iron. The oxygen of the flame is taken up by the carbon contained in the first bath of iron, and the flame is thereby made a reducing one before it passes the bridge; the latter is sometimes also covered with pieces of coke or charcoal, so as to add still more carbon to the composition of the flame before it passes over the second bath of molten iron. The process is usually carried on so as to have fresh pig iron on one side, while a nearly decarburised material is contained in the second compartment, one change of currents only being made. The fresh flame, therefore, always passes over the crude pig iron first, and afterwards reaches the decarburised mass, which it converts into steel. M. Berard is very far from having as yet got his process into anything like a practical working condition. The small quantity of good steel he has produced hitherto is the pick of a disproportionate amount of failures, and to all those who are acquainted with the difficulty which exists in removing sulphur and phosphorus from the iron by the oxidising influence of the air, it must appear extremely unlikely that the means resorted to by M. Berard, however protracted their action may be, can effectively serve the purpose for which they are intended. M. Berard also intends to add mixtures of wrought iron, steel scrap, and other similar matter to his pig iron, but for this he has no special claim as an inventor, the process of mixing pig iron with decarburised iron, or with iron ore, being very old and universally known. Messrs. Emile and Pierre Martin have introduced a system of steel manufacture which is of far greater practical value and importance, although it contains no more novelty in its abstract principle than the first-named process. Messrs. Martin, however, have succeeded in making their process a commercial success. The Martin process is now in operation at the works of Messrs. Schneider and Co., at Creusot, at Messrs. Verdie's, at Firmini, and in three or four other French steel-works, and its results are very satisfactory, both with regard to the quality of steel produced and to its economical production. Messrs. Martin's mode of operation consists in the following process: A quantity of pig iron, say a charge of 3 or of 5 tons, is melted, in a Siemens furnace with a dish-shaped bottom, or it is run into the furnace from a cupola or blast furnace. It is then exposed for about half an hour to a very high temperature, care being taken to keep the flame slightly overcharged with gas, by which means the burning of the fire-bricks of the furnace-top is said to be avoided or lessened. After that time a quantity of wrought iron, scrap steel, scrap or iron ore, or a mixture of these substances, is added to the mass. The additions are repeated in intervals of about thirty minutes, and they are made at charges of about 2 cwt. at each time. The articles charged into the furnace are all previously heated to redness, so as to avoid any cooling influence upon the liquid mass. The process continues in this manner for about six hours. Towards the end of the operation the temperature of the furnace is raised as far as the nature of the combustion will permit. The quality of the metal produced is carefully tested from time to time by removing a small quantity of metal from the furnace, and casting it into a small ingot mould, the ingot being afterwards tried under the hammer. The operator has thereby, at all times, complete control over the course of the process. He can judge how near the product obtained at any given moment comes to the desired quality of steel, and he can adjust his operations and additions accordingly. Messrs. Martin have found it advisable, in the production of steel, to follow the same course as has been adopting in the Bessemer process, viz., to decarburise the iron completely at first, and then to add a sufficient quantity of spiegeleisen to effect the desired combination of iron and carbon. In M. Martin's process the facility for working up old iron and steel scrap is a very important point. The conversion of old iron rails and of similar articles into steel has become a great desideratum in our recent practice. In the Bessemer process this is feasible, but the proportion of wrought iron which can be added to the pig iron in the converter is comparatively small, and any excess endangers the proper fluidity of the charge. The largest proportion of wrought iron that has, to our knowledge, been added to a charge in the Bessemer converter was 30 per cent. of old rails mixed with very grey hematite; but then the rails were thrown into the converter at a welding heat, and the pig iron run upon them immediately. M. Martin says that he can use two-thirds of old rails with one-third of pig iron without difficulty, only the rails must be of good iron, free from sulphur and phosphorus, since the Martin process will no more remove these elements from the iron than the Bessemer process will. Messrs. Martin have produced the same graduation of metals, containing more or less carbon in proportion, as has been obtained by the Bessemer process. They make a 'mixed metal,' half cast iron, half steel, the same as Mr. Bessemer uses for his hammer heads and anvils. They produce tool steel of remarkably good quality, also soft steel, or homogeneous metal, and ultimately the very softest kinds of decarburised iron, to which they have given the name *fer fondu*, or 'cast wrought iron.' This latter substance is somewhat similar in its nature and appearance of fracture to the homogeneous iron shown in the exhibitions of several iron-works in the British section. Messrs. Martin's process seems to be worthy the attention of British steel-makers, and it is very likely to come in as a very useful addition to the Bessemer process for working up scraps and old materials into marketable steel."

(e) *Cleveland Iron at the Paris Exhibition.*—Mr. John Dixon, of 5 Abchurch Yard, London, thus writes to the editor of "Engineering:"—"In a previous paper I see a favourable notice of the few samples of iron produce of our Northern District which the scanty space granted by the Commissioners has enabled me to display in the Paris Exhibition. I regret that none of our larger manufacturers have deemed it worth their while to be represented there, as it certainly would have been for their own benefit, as well as that of the locality. That absence, however, I believe is entirely owing to the slight attention that was paid to the approaching Exhibition until the space had been allotted.

The proper objects of industrial exhibitions, I take it, should be to afford a comparative view of the actual manufacture of various countries and localities; not, as is too frequently the case, to make them a medium for special advertisement, by the exhibition of monstrosities and articles produced regardless of expense, which display nothing but the amount of reckless extravagance indulged in for the sake of notoriety and display.

I have simply selected a few samples of the iron which is being manufactured every day in our northern district, to show not what can be done, but what we are doing, in the hope that it may contribute its mite to remove the prejudice and partial views which still in some quarters exist, but which time and experience of the quality of the iron will in due course eradicate.

Cleveland iron of the present day is a very different material from that of ten or fifteen years ago, when the trade there was in infancy, and the manufacturers were inexperienced in the manipulation of the raw materials on which they had to operate. The interest excited by the discovery of the abundant supply of ironstone in Cleveland had the natural effect of causing consumers in all parts to test by experiment the merits of the new iron, and in many cases they jumped to conclusions on the youthful productions of the district, not in all cases favourable to a fair estimate of its merits in more mature age.

The stone itself is not a rich one, averaging, as it does, about 30 per cent. of iron, which varies considerably in different localities. But the coal and limestone requisite to fuse and flux it are equal to any in the world, while the facilities for the importation of ores from other districts and countries now give to the manufacturer a variety of choice that affords him the means for combination, so as to produce exactly the quality of iron best suited to his purpose at the lowest possible price.

The rich hematites of Cumberland and Westmoreland, used in such prodigious quantities, neutralise the inherent 'cold-shortness' and defects of the native stone. The ores of Devonshire and Cornwall and Scotland, of Spain, France, Algeria, and Sweden, are either, as in the latter case, specially imported by steamers employed in that trade alone, or find their way to the northern ports at the lowest possible rates, as return cargoes for vessels which have gone out with coals.

Ten years ago the total annual produce of pig iron was about 350,000 tons. This had increased last year to about one million and a quarter; and when returning activity in business brings into blast the new furnaces now ready or in course of construction, an annual output of one and three-quarter millions of tons will be reached—a quantity approaching, for this one spot alone, that of all the rest of Britain put together. Of these quantities about one-fourth is converted into malleable iron; the rest is either used in the district, or finds its way into Staffordshire, Scotland, France, Belgium, Germany, and, in fact, to all the iron marts of Europe and America, who find it cheaper to purchase Cleveland pigs than to produce their own.

The first result of this prodigious increase of supply is naturally to keep down price, but on the slightest decline of demand it stimulates that keen competition, in cheapening by every means the cost of production and improving the quality to secure the command of the market, which results in the immediate application of every new improvement, and the introduction of fresh machinery and appliances, embodying the teachings of the most recent experience. In such a race none can afford to be idle; each new furnace erected embodies some peculiarity in advance of its predecessor. Two hundred to two hundred and fifty tons a week is by no means an exceptional yield for a single furnace, and some now erecting are meant to improve even on this. Yet, ten years ago, I see, by reference to an old furnace-book of my own, that a hundred to a hundred and twenty tons was deemed satisfactory.

As to cost. this iron at once commends itself to notice, but in the more crucial test of quality the path is not so clear. Old prejudice cannot be readily removed, especially when fostered by rival jealousy, and, as it must be candidly confessed, in its earlier years, the quality was not all that might be desired; but such great changes have been effected, that all now required is the fair field of candid trial and no favour, when it can hold its own against the world. Time was when the very idea of using it in their works would have frightened our leading engineers; but one by one they are coming round to acknowledge that in the possession of those qualities of great tensile strength and toughness, which are essential in engineering works, it is everything that can be desired. Many of the principal bridges constructed of late are made of it. On the Clyde it successfully competes with Scotch for shipbuilding, and the hard surface and clean skin possessed by the plates render it less susceptible of corrosion and consequent fouling of the ship's bottom than any other, which is an advantage that, when combined with toughness, is also desirable in boiler work, and is causing it to be used by all our principal engine builders for those boilers, or parts of boilers, where the prestige of Low Moor is not a *sine qua non*.

But the most crucial test of all is in the supply of the Government dockyards, where a large staff of officials and inspectors are employed for the sole purpose of finding fault and insisting on the most rigid test of every description.

Year by year this iron has been steadily forcing its way, and it has been employed in the construction of the Achilles, Bellerophon, Valorous, Resistance, Black Prince, and many others of our iron fleet. The entire supply of plates required in the Government dockyards is now in the hands of Cleveland manufacturers, and there, I imagine, it is long likely to remain. The iron supplied is thoroughly up to the standard, and is giving the most unbounded satisfaction, as the following list of vessels now being built of it at the various dockyards must show:—

At Chatham,	Monarch
,,	Myrmidon
,,	Hercules
,,	Caisson
,,	Beacon
,,	Dwarf
,,	Blanche
At Devonport,	Vixen
,,	Fly
,,	Lapwing
,,	Seagull
,,	Flirt
At Deptford,	Thistle
,,	Boxer
,,	Plover
,,	Nymphe
At Portsmouth,	Dido
,,	Cracker
,,	Avon
,,	Elk
,,	Sirius
,,	Danaë
,,	Swallow
,,	Magpie
,,	Ringdove
At Pembroke,	Inconstant
,,	Gnat
,,	Penelope
At Sheerness,	Sappho
At Woolwich,	Repulse

In conclusion, to quote from the article in your paper which has called forth these remarks, 'I trust these facts do indeed indicate a recent and very marked improvement of the Cleveland district, and do show that improved practice has so far overcome the difficulties inherent to the manufacture of iron from inferior ores, that cheap production is no longer incompatible with a high quality of material produced.' "

(*f*) *Castings at the Paris Exhibition.*—From the "Practical Mechanics' Journal," Nov. 1, 1867, we also take the following:—"Beautiful ornamental castings in iron are shown by Prussia, and some by other states, but none approach in excellence those which are exhibited by France. Statues, even of colossal size, others copies from the antique, figures of animals, pedestals, panels in *basso relievo*, open-work scroll grilles, ornamental columns, balusters, cantilevers, and innumerable smaller objects are shown, in most of which one is divided in admiration between the beauty of the artist's part in the performance—viz., the perfection of the model—and that of the workmanship due to the moulder, and to the choice of the iron. The whole nearly of these figures and castings are exhibited just as they left the sand, some without even the 'gaits' having been cut off. Nothing can exceed the beauty of the sanguine blue colour obtained upon the skin of these castings, nor can anything be finer than the smoothness and texture of their surfaces. Some of the figures, copies from the antique, are from subjects the least promising to be able to reproduce happily in that suggestively intractable material, cast iron such as the Apollo of the Vatican, the Venus de Medici, &c.; yet so good have been the lines of the models, so judiciously have they been slightly altered in proportion, so as to suit this rigid character without losing their suggestion of softness, and without being distorted by contraction in cooling, that we have never seen bronze statuary more pleasing to the trained eye in its effects. Some of the animals are most meritorious creations; two large lions, for example, one *couchant*, the other sleeping, with genuine shaggy manes, real leonine expression in their faces, and covered all over with an unmistakable coat of hair, may well put to shame our gigantic tom cats, with judges' wigs upon their pates, in Trafalgar Square.

In another and very different class of castings in iron, France exhibits some very satisfactory examples. Amongst these is a complete set of water pipes for Paris, from a meter or so in diameter downwards. These are cast in great lengths in loam and vertically, some as much as 7 meters long; they are mere straight cylinders without faucets, and are put together with collars cast separately. A huge pile of these lengths is shown standing inside each other, and out of each of which a large elliptical-shaped *gobbet* has been cut, so as to show at once to the eye the relative thinness, perfect cylindricity, and absolute uniformity of thickness of the whole. Castings in bronze and brass are exhibited by several celebrated manufacturers in France. The bronze statuary and other ornamental castings of MM. Voruz, of Nantes, are highly meritorious: numbers of these, including amongst this collection fine busts of the Emperor and Empress, are shown just as they came from the mould, with all the 'gaits' and 'air vents' still adherent. Their brass castings have to the practical eye of the brassfounder perhaps even greater merit than those in bronze. The practical brassfounder knows well how hard he finds it always to preserve upon the exterior skin of his *brass* castings a perfectly uniform, unbroken, and, as it were, unfolded-over skin. Brass, at the high temperature at which it must be poured, has so intense a tendency to oxidate that it is scarcely possible to prevent an ugly film of oxidated skin from forming at the mouth of the gait, and passing into the mould, and so getting to the surface of the casting. Many an otherwise sound piece of brass casting becomes useless for 'finishing up,' because beneath this skin often lie concealed minute air bubbles or drossy crusts.

These French brass castings present very few symptoms of this, or of any other defect. Of brass castings for the common uses of the mechanician or plumber, &c., there are multitudes exhibited by almost every forward European nation. None are better in material than those exhibited by Germany, by Belgium, and by England. In finished brass work, such as cocks, valves, couplings, oil cups, hydrants, &c., all, in fact, that forms the trade of the great Rotherham and London houses in engineers and plumbers' fittings, none are, we think, so good, material and work considered, as those of England and Belgium. France produces much finished brass work of this sort of great excellence, but she also presents a good deal (as do some of the German states also) of brass work formed of a very soft and debased alloy of copper and zinc; one, no doubt, of a fine light gold colour, but too soft for durability. Whitley & Co., of Leeds, in company with many more, show a good deal of brass work for railway use, and have, we believe, received a silver medal."

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DIVISION EIGHTH.

RAILWAYS.

55. *Railway Carriages.*—The following, by John Page, C. E., is one of the important papers of the year:—" A great proportion of the loss of effective power in propelling railway trains is due —1st. To the resistance caused by the employment of small wheels. 2d. To the resistance of the air; and, 3d. To the resistance caused by the friction of the wheels against the rails, when brought in contact by the lateral oscillation of the carriages. I propose to show the mechanical advantages to be gained by the use of larger wheels, and the possibility of their introduction in carriages much lower than those at present used. These points gained, we have the centre of gravity lowered, less resistance presented to the atmosphere, and, consequently, greater safety guaranteed. Allusion will also be made to the errors in the principle of con-

struction of the carriages as they are now built, not with the view of stating anything new, or presenting more than a brief outline of what has been done or said in the matter, but with a wish to exhibit the vast importance of a subject involving the reduction of the working expenses of every railway, while, at the same time, the comfort and safety of the travelling public would be increased.

Such questions as these were fully discussed during the time the 'Battle of the gauges' raged, the records of which read *now*, in the light of our experience, present a few useful lessons. Amongst those who, at the time, advocated 'things as they are,' I find that an eminent engineer asserted, there was no danger of the carriage overturning; that, from what experience he had of railways, he believed it would be a most difficult matter to overturn the carriages upon them, even if the object was purposely to do so, and an experiment should be made for the purpose. In lowering the centre of gravity, and in making the wheels larger, he saw no difficulty, and was quite sure, that inasmuch as these alterations have not been made, there is evidence to prove that they are unnecessary. But after all he did see a difficulty, for he proposed to make the carriages omnibus fashion, certainly not an economic arrangement, and certainly not one to be desired. He considered the carriages safe, and said, 'as things are safe there cannot be the smallest advantage in making them safer!'

Although I cannot agree with Mr. Brunel in the necessity of increasing the width of gauge to obtain greater safety, higher wheels and less resistance to the atmosphere, because the improvements can be attained on the narrow gauge, yet I do admire the moral courage shown by him in venturing upon an untrodden path, for all his predecessors were mere imitators, adding or subtracting as their fancy dictated; showing as little variety as we see in canals and in canal boats; and I am not astonished, that this 'Arch Innovator,' as he was sometimes called, should have considered himself unfairly dealt with, when facts, the results of careful experiments, were thus met, particularly so, when those who were interested in perpetuating 'things as they are were brought forward to prove that as things were tolerably well it was useless to seek for better. His pertinent remark *then* is not *now* without its value. He said:—I have the pleasure of being personally acquainted with the gentlemen whose opinions are quoted, and entertain the greatest respect for them; but I should never have thought of consulting them. If before building the Great Western steam ship we had written to some of the highly respected and talented gentlemen who commanded the New York liners, and asked them, if *they* considered there was any danger or inconvenience in the use of sails, and whether they should prefer steam, I think we might have anticipated their answers.'

I am not wedded to my plans. I do not consider them the best possible, nor do I presume to say it is for the present interest of railway companies to fall in with all that I propose, although they must prospectively look these matters in the face and follow in the march of improvement. I am only anxious that the subject may be fully discussed, and I hope that the term 'safety' may be used comparatively, as it must be admitted that there is a possibility of danger, arising from various causes, although it is generally supposed that the railway carriages are not easily overturned. Yet we cannot shut out the idea from our minds, that there is a susceptibility of the carriages to be thrown off the rails; and apart from this, we know such does sometimes happen, and that there is really serious cause for being alarmed.

The carriages, as they are now made, are perched high over the wheels, and have a tendency to pitch and lurch—two motions neither agreeable nor safe. This tendency was sought to be overcome not by removing the cause, but by adding a contrivance, complex and expensive, called a buffing apparatus. In 1835, Mr. Bergen, of the Dublin and Kingstown Railway, took out a patent for an improvement on the then existing buffer apparatus, which has been superseded by Mr. Booth's improvement. It certainly, when properly used, does go far to impart a steadiness and smoothness of motion at rapid speeds; but it must be regretted, that such an expedient is absolutely called for to obtain such results.

Curves, under the most favourable circumstances, are highly objectionable, partly arising from the construction of the carriages, which is such as to be rigidly square in all its details; in fact, we may say the wheel moves in a straight groove, or what is equivalent to one, and unless there is some yielding of its parts doing actual violence to them, it is impossible for a carriage move in any direction but that of a straight line. This evil to one carriage is magnified by the coupling; for when the coupling is correct and all the carriages are brought tight to their bearings, the train is represented by a strong straight cane, yielding, it is true, to the bends of the road, but such yielding is at the expense of great friction, great straining, and shearing of the rails and wheel flanges. But curves are unavoidable, and as the carriages are now constructed we are compelled to use the coupling to steady the train; but like the man with the crutch, we acknowledge the assistance it gives, while we regret the necessity which obliges us to use it.

Bad couplings, axles and springs breaking, are admitted to be the proximate causes of many accidents. That such accidents are not more frequent, we are thankful to the ever watchful care of those who have the superintendence of railway plant; but I hold that it would be well, and I think it is possible to reduce the hourly dependence on human watchfulness, which, with Argus eyes, must be ever awake, consequent on our present system; not that I would diminish the attention, care and watchfulness at present existing, but that I might in a degree lessen the danger resulting on neglect of duty. I will now allude to the technical advantages to be gained by using wheels of large diameter.

The advocates of the broad gauge deemed the most important part of the advantage to be gained by their system, to be the facility with which they could increase the size of the wheels, without raising the bodies of the carriages. It was proposed to place the body of the carriage between the wheels, and in thus lowering the centre of gravity, it was calculated that greater stability and smoothness of motion would be attained, 'as high carriages are more liable to oscillate, and that a very considerable part of the friction was occasioned by the rolling of the carriages, throwing the flanges of the wheels against the rails.' But the idea of bringing down the centre of gravity was not carried out, for in using wheels a little higher than those on the narrow gauge, the carriages were actually raised, instead of being lowered, thus presenting a greater resistance to the atmosphere. The broad gauge had many objectors, but they all agreed that it was desirable, if possible, to have larger wheels than those in use. The late Mr. Nicholas Wood, honorary member of this institution, in his report on the Great Western Railway, admits that there is a diminution of friction by increasing the size of the wheels.

Mr. W. Bridges Adams was also a great advocate for high wheels. He, too, proposed to place the body between the wheels. He condemned the present system, and proposed in the construction of passenger carriages to abandon the under carriage altogether; to have a body capable of containing, say 12 persons, placed between two wheels, four feet or four feet three inches high, the bodies to be coupled together by jointed iron work, 'leaving about 3 inches of space between the bodies in order to allow the axles to accommodate themselves to the line of draught;' he adds, 'that with carriages of this description, a whole train might be jointed together without the necessity of buffing springs.' But this carriage is only wide enough to accommodate two persons on each seat, carrying only eight instead of twelve persons.

Mr. Thomas Tredgold remarks, that it seemed quite clear to him, that as far as the friction of the axle is concerned, if you double the radius of the wheel, you reduce the power necessary to move the carriage one-half, and expresses his astonishment, that this truth, although repeatedly published in this country, has been overlooked by many. To confirm his idea, he instituted a series of interesting experiments. He had a small carriage made with two sets of wheels, one set being 4 inches and the other 8 inches diameter; he used revolving axles of iron 0·55 inches in diameter, working in brass bearings, so that in changing the wheels no change was made in the rubbing surfaces. The wheels were of cast-iron, and the rims turned. The rail was 12 feet long, filed straight and smooth on the upper edges.

In the first experiment, the 4-inch wheels were used, and the carriage was loaded till a weight of 4 lbs. passing over a pulley, and drawing in a line parallel to the rails, produced a regularly accelerated motion on the rails, adjusted so that the first 3 feet were described in 9 seconds, the total weight of carriage and load was 230½ lbs.; so deducting the friction of the pulley from the 4 lbs., it was ascertained that the load was moved by $\frac{1}{59\cdot4}$ part of its weight. The 4-inch wheels were then removed, and the 8-inch ones put on the axles, the pulley being adjusted to render the line of traction parallel to the rails, the moving force of 2 lbs. was applied, and the load increased till the first 3 feet were described in 9 seconds. It was then found to be 219·75 lbs., including the carriage and wheels as before; consequently the load was moved by $\frac{1}{115}$ of its weight. It thus appears that a load of 230·5 lbs. was drawn by a weight of 4 lbs. with 4-inch wheels, being moved by $\frac{1}{59\cdot4}$ part of its weight, and a load of 219·75 lbs. was drawn by a weight of 2 lbs. with 8-inch wheels, the load being moved by $\frac{1}{115}$ of its weight. These experiments show that the resistance does not decrease exactly one-half by doubling the size of the wheels; but the difference is not much from that ratio. Mr. Tredgold remarks, that as the experiments were repeated frequently, with as little variation as could be expected, that it may, for rail-roads, be assumed that the power in the same circumstances as to axles and pressure, is inversely proportional to the diameter of the wheels, or very nearly so.

We will now consider the retarding effects of the air on the motion of the carriages. Dr. Lardner was the first person to call particular attention to the fact, that this resistance increases with the square of the velocity; but as far as my reading goes, he did not appreciate it to its full value or extent in its effect on railway carriages. His experiments are well known, showing the loss from this cause, and several of them are quite conclusive on the point. In one of them, the half of the front part of a waggon was made to fold down on a hinge joint, so as to expose only half the surface, when required, to the atmospheric resistance; the waggon, being loaded, was started down an incline with the whole of the end surface exposed, and afterwards with the same load and only half the surface of the end exposed. After minutely detailing the results, Dr. Lardner observes—'It appears, therefore, that with the frontage of 47′·8 square feet this train suffered a greater resistance at 8½ miles an hour, than that which is sustained with the lesser frontage of 23′·8 square feet at 19½ miles an hour.' The general conclusion arrived at by Dr. Lardner was, that the atmospheric resistance to the passenger trains moving at 30 miles an hour is equal to 15 lbs. a ton of the gross weight of the train. Taking then an increase at the square of the velocity, we find the resistance to amount to 60 lbs. a ton to a train moving at the rate of 60 miles an hour. It has been asserted that the resistance is due to the end of the first carriage only, forgetting that the strong wind, which must be encountered occasionally at every bend of the road, acts either in the line of motion obliquely, or at right angles to it.

Dr. Lardner did not seem to be quite clear on this point, for he observes, it should also be remembered that the resistance of the air to a train of coaches does not act exclusively on the front of the first carriage; the carriages of the train are nearly four feet asunder, and the air probably acts more or less on the foremost end of each carriage. This idea was entertained by Mr. H. Bessemer, who made some ingenious experiments to ascertain the amount of resistance due to the end of each carriage in the train, and as the experiments may be interesting, I will attempt to show the results arrived at. The model train required five horse power to move it at a velocity of 45 miles an hour. The carriages were constructed on a scale of $\frac{1}{8}$ size of those in use on the railways. A spring balance of a good construction was used, and the indications were marked on a card by a pencil tracer. All arrangements being complete, the train was put in motion, and the speed gradually augmented from the time of starting in each experiment; and when the number of revolutions per minute was attained, which was equal to the number of miles per hour previously determined on for each series of experiments, the speed was gradually diminished till the carriage was brought to a state of rest, when the indications on the card were copied off, and the same experiment twice repeated, so as to obtain in all cases the mean of three experiments. The first series indicated a resistance of 2·1 lb. of front surface of carriages at 20 miles an hour; 3·2 lbs. at 25 miles; 4·5 lbs. at 30 miles; 6·1 lbs. at 35 miles; 7·9 at 40 miles; and 10 lbs. at 45 miles an hour. Having thus ascertained that the pressure was exactly 10 lbs. on the end of the carriage a foot square, a second carriage was placed behind the first, with the space between the buffers left open as is the present practice on railways, the two carriages being put in motion at the selected rate of 45 miles an hour, the resistance indicated as the mean of three experiments was 14·1 lbs.; say 4 lbs. as an addition per superficial foot of the second carriage. A third carriage was connected, the indication was now 18 lbs., showing an addition of 4 lbs. for the third carriage. Three more carriages were successively added, and the result in each case was precisely 4 lbs. per superficial foot. The spring balance indicated a resistance of 30·5 lbs. per square foot of frontage with a train of six carriages. This result, the first step in the experiment, having been attained, the plan of reducing the atmospheric resistance by filling up the spaces at the ends of the carriages was next tried; for this purpose, five small hoods of wood, made to fit into and fill up the spaces between the ends of each carriage, were prepared. One of these hoods was placed in between the first and second carriages of the train of six, which then presented externally the appearance of a double carriage, without any space between them for the atmosphere to impinge against. The speed of the train was now increased to 45 miles, and the mean of three experiments showed a diminution of 4 lbs. in the general resistance. A second space was then filled in, the train brought to the same speed, which resulted in another reduction of 4 lbs. The remainder of the spaces were successively filled up, with like results in each case. The train now presented the appearance of one long carriage, without any break or interval to catch the air, and the experiment clearly demonstrated that as the resistance was now reduced to only 10 lbs., being precisely the same as that of a single carriage, that in the case of a train of six carriages, two-thirds of the atmospheric resistance could be saved by merely filling up the intermediate spaces.

Mr. Bessemer pushed his inquiries further, with a desire to reduce the 10 lbs. resistance, if possible. With this view, he formed the front of the train wedge form, and on experiment the resistance was reduced to 6·3 lbs. Much is due to Mr. Bessemer for his painstaking and interesting experiments, in which he clearly proves the resistance of the air in front of the carriage has a great retarding force; but I think his mode of cure is a clumsy one. It is to my mind a patching up of what must be admitted is radically wrong.

Mr. Robert Stevenson has also given much thought and time to this question. In his very able report on the Dalkey and Kingstown Railway, recording the results of his experiments, he says, 'There is no alternative but to ascribe the *enormous* loss of power to the resistance of the atmosphere.' In the experiments now referred to, we have confirmation of two facts:—that at the high rate of travelling on our railways, a great loss is sustained by the resistance of the air, and by the use of small wheels. To meet these evils in the present system, I have devised a mode by which they may be overcome. The Victoria Carriage is only nine inches from the rails. No platform is required. Its appearance, considered under the question of safety, is in its favour, and it is hoped that the first impressions will ripen, on more intimate acquaintance, into a conviction of its worth.

This carriage is composed of two first and two second class compartments. It will occupy in a train about 9 feet more than a carriage as now used would in affording similar accommodation. Although longer, it presents rather less area to the resistance of the air on its side; at the same time the centres of gravity and pressure are brought low, and the angle of stability increased. To show the vast importance gained in these three points, I will refer to a curious and interesting accident which happened to a train on the Holyhead Railway during a severe snow storm in the early part of this year. The wind, whose great retarding force on railways has been so long overlooked, gave a practical lesson of its power, as it rushed down the valleys between the mountains on the southern side of the line, not far from Bangor, and blew over the Post-office van, only shaking the officials without injuring them. The wind might have struck the carriage, smashing it to pieces, and adding a few to the figures under the head of accidents resulting from 'causes beyond the control of the company's servants.' It might have taken a step or two higher and sacrificed a bishop, but in attacking a royal carriage it seemed desirous to bring home to royalty itself a full knowledge of its power. I hope the hint will be taken, and that an effort may be made, in lowering the centre of gravity, to render travelling by rail more safe than it now is. Wanting the weight and size of the van, it is impossible to arrive at what force was exerted by the wind in overturning it. I will take the Victoria carriage and the Ashbury carriage and compare them under the influence of a strong wind. I calculate that the Ashbury carriage, weighing with its passengers 11 tons, will require 31½ lbs. per square foot to overturn it, and that the Victoria carriage, carrying the same number of passengers, weighing also about 11 tons, will require a steady pressure of 53 lbs. per square foot to overturn it. This is a great difference in favour of the low carriage.

The experiments of Mr. Robert Stephenson, Dr. Lardner, and Mr. Bessemer, were confined exclusively to the resistance on the ends of the train. This is entirely got rid of in the new system, as the tender stands higher than the carriage. Thus a surface of about 22 square feet disappears, which in the present system has been proved to offer an enormous resistance at high velocities. The under carriage is a two-wheel bogie, turning on the usual centre. It is connected to the bogie of the next carriage by a sliding iron rod, forming, when so coupled, a four-wheel bogie; but each two-wheel bogie has freedom to advance or recede as the buffing apparatus comes into action, still keeping the faces of the wheels in line with the rails. I am not sure that the coupling of the bogies is necessary, as I have observed two-wheel Bessel bogies under engines, and I have every reason to suppose that it will answer as well under a carriage. The connecting apparatus is simply a buffing and drawing one, and makes no pretensions to steadying the carriage, as it does not require such aid; being hung at the ends and above the centre, there would be no pitching or lurching, and, I may add, no danger of overturning. The wheels are 4′-6″, but may be higher if thought desirable. The framing of the carriage is proposed to be formed principally of iron or steel. The whole strength of the body depends on the top; from it down the body is trussed, and can thus be made to carry any weight required. In consequence of the under part of carriages, such as wheels, axles, springs, &c., failing, a stock of carriages is required to keep up the probable wants of the traffic; on the new system the bogies will only be required in stock, and an injured one can be replaced by a perfect one in a quarter of an hour. There is a safety bar under the flooring at both ends, which, in the event of an axle or spring breaking, would come on the rails and keep the carriage there; in such a case the fall would be only 9 inches. It is drawn from the top, but the drafting rod and buffers may be placed to suit the carriages of the present system.

The Victoria carriage, for the purpose of comparison, is designed in the same proportion as the Ashbury carriage, but I propose a breadth of 9′-6″ for the new carriage, and giving it additional length, so as to carry 16 of first class and 36 of second class passengers. Its weight with carriage would not exceed 3¼ tons on each wheel, which is considerably under what is carried by the wheels of some of our locomotives. I have been examining the defects of the present system of railway carriages from an engineering point of view, but I have yet to consider it under a sanitary one. The crowded state of our cities sends us longing to the country for repose and for the pure and invigorating air, and the facilities afforded by our railways induce thousands to reside out of town; but I am informed that in many cases this advantage is dearly bought. Who, on arriving at the station, can resist the tempting morning paper, the city, home, and foreign news, which, with the leading article of the favourite paper, have all their charms to the enquiring and busy mind; and dull indeed that man must be who can sit during a run of 15 or 20 miles without trying to get a glimpse of the busy outer world, as is shadowed forth in the daily papers; but it is in thus trying to do so as the carriage swings from side to side that the danger lies. In the efforts made to catch each word and hold it, so to speak, with its neighbour, the paper dances before the eyes, they become dimmed, the head heavy, and the back strained, as the body of the reader endeavours to go with each motion of the carriage; but as the motions are compound ones, the efforts are in vain, and the consequence is, a dullness is felt for an hour or so after emerging from the station. This slight affection is produced daily for years, and slowly yet surely undermining the health, we get accustomed to it, and the bad effects, if observed at all, are not traced to their first cause until too late. I regret to say that I can, in my limited circle of friends, number a few such cases.

The constant vibrating and jerking of the Post-office van must render the labours of the sorting-clerk exhausting to both body and mind, particularly as his services are rendered during the night, and the principal part of the time standing. Sir Francis Head, as he sat reclining and ruminating in a corner of what he called a flying post-office, remarked that in consequence of the rapid rate of travelling the bags which were hanging from thirty pegs on the side of the van had a tremulous motion, which at every jerk of the train was changed for a moment or two into a rolling or pendulous movement, like towels or cloths hanging in a cabin at sea, or the dancing of a hat suspended from the roof of a second class carriage. Even the most ardent admirer of our present carriages, and the warmest advocate for things as they are, will admit that it would be well to have our carriages lower without reducing the size of the wheels, and desirable to reduce the unpleasant motion so much complained of to that of a smooth and uniform motion. Yet I cannot shut out from my mind that there are difficulties in the way of a change. But I have a hope, as I look at the drawing of the Rocket of 1829, and read the opinions of the men of eminence then in reference to the locomotive, and to employing it on railways, how it was called a hopeless project; the idea was ridiculed and stigmatised as absurd of its ever being able to draw a train of 20 tons at the rate of 12 miles an hour. Yes, I have hope, as I turn to the locomotive of this day, and gaze upon the wonderful improvements made, and which are being made on it, that engineers will turn thei attention now to the long neglected carriages."

56. *An American View of the Rolling Stock of English Railways.*—"Owing to the excellence of the permanent way," says Mr. "Slade" in the "Scientific American," "some arrangements, which on our roads are necessities, have not been as generally introduced in English locomotives; and while with us makers have settled on one or two types of engine exclusively, the variety of arrangement here is much greater. There are many lines, however, which of late have adopted several American ideas, such as the Bissell truck, the equalizing bar between coupled drivers, and placing the steam chest on the top of outside cylinders; and it is probable that the use of most of these will ere long become general. The English locomotive, however, though unfit for American roads, is nevertheless, for the roads on which it has to run, an excellent machine, and presents some points which we would do well to copy. For good engines the type most generally adopted is six coupled driving wheels, about five feet diameter, without other wheels. For an engine of twenty-seven tons' weight, the amount on each pair of wheels would be about nine tons on the forward pair, eleven and a half on the centre or driving axle, and six and a half tons on the after pair. Such an engine would have cylinders eighteen inches diameter by twenty-four-inch stroke, with a thousand square feet of heating surface in the boiler, and carry one hundred and twenty lbs.

steam. For passenger engines there is greater variety. The majority have inside cylinders, though a respectable proportion have outside. A favourite plan has been to give but a single pair of driving wheels, of from six feet six inches to seven feet six inches diameter, with one pair of leading and one pair of trailing wheels, of three feet six inches diameter; cylinders sixteen inches or seventeen inches diameter, by twenty-four-inch stroke. The driving wheels in these carry eleven or twelve tons, but, as we should suppose, they are often deficient in adhesion. Four coupled wheels are now more in favour, either with a single pair of leading wheels, or with a four-wheel bogie. The largest diameter of coupled wheels is seven feet. There is hardly any arrangement of wheels that may not be found in quite general use, two pair of driving wheels alone, four drivers, and a pair of trailing wheels, four drivers and two pair of leading wheels, or a single pair of driving wheels and a bogie, but the first-mentioned forms are perhaps the most usual. The boilers are made of seven-sixteenths-inch plates in the shell, five-eighths or three-fourths for the forward tube sheet, and copper fire-boxes half inch thick, except the tube sheet, which is three-fourths inch thick reduced to five-eighths inch below the tubes. The water spaces around the fire-box are two and a half to three inches wide. The circular seams of boilers, as a general thing, are single riveted, while the longitudinal ones are double riveted, three-fourths inch being the usual diameter for the rivets. As this plan is not generally followed with us, it is worth while to call attention to the reason why it is done here, and why it certainly is the right way to build boilers. The strain on any joint or section of a boiler is proportioned to the area acted upon by the steam divided by the amount of length of section of metal to resist the pressure. Now the pressure, tending to tear asunder the circular seams is due to the area of the ends of the boiler, and is resisted by a length of section equal to the circumference. The pressure tending to rupture the longitudinal seams is due to the diameter of the boiler multiplied by any unit of length, and the resisting section of metal is twice that unit of length or the amount on each side of the barrel in that length. Now as the area of the end is equal to half the circumference multiplied by half the diameter, the strain on the circular seams, which is as this amount divided by the circumference, will be as the diameter divided by four, while on the longitudinal seams it is as the diameter divided by two, or twice as great per unit of length. If, in addition to this, we consider that the area of the heads taken up by the tubes, on which there can be no pressure, is very great beside the proportion of the strain that they themselves bear, we see that the circular seams always have a great excess of strength over the longitudinal ones, and hence the propriety of double riveting the latter. Angle iron is used in the construction of boilers to a larger extent than we should think advisable, though the best builders only use it for fastening the forward tube sheet to the shell.

The tubes are always of brass, and are set with steel ferrules at one or both ends. Steel is coming largely into use for boilers, on account of its great strength and the facility with which it can be flanged to any desired form. It may reasonably be expected, also, that the reduction of the thickness of the plates, consequent on the substitution of steel for iron, will remove a difficulty which is always found with English locomotive boilers, but which is unknown in America, viz., the grooving of the plates just at the end of the lap of the circular joints in the submerged part of the joint. This has always been a most serious trouble, since the plates are reduced to an unsafe thickness just at this part long before the remainder of the boiler is at all impaired by use. This cannot be due to bad calking, for it occurs in places where no calking is done. It is attributed by some to the strain caused by expansion, tending to buckle the plates, especially where, as in some cases, no expansion joint on the frame is provided; and if this be the cause it would no doubt be less serious with comparatively flexible thin plates than with the thicker ones. The adaptation of the fire-boxes to the burning of bituminous coal is generally very simple and quite effectual. On the London and South-western perhaps the most complete combustion of the gases is obtained by the use of large quantities of fire brick in the form of tubes, arches, and gratings, to insure the requisite heat for ignition after the air for combustion has been admitted; but as this system is very heavy, and not readily applied to existing boilers, it has not come into as general use as other less expensive and scarcely less perfect means. The most usual plan is to have an arch of fire brick projecting from just below the tubes, about half way across the fire-box, and under this air is admitted through two openings in the front of the fire-box seven inches square, provided with dampers by which the quantity can be regulated. Or the air may be introduced at the door, and thrown down toward the arch by a deflector of old sheet iron, in either case the air being obliged to mingle with the gas and ignite before entering the tubes. Sometimes the deflector is used without the fire-brick arch, and in some cases there is no fire door at all, though, unless the firing be constant, this must, I should think, admit too much air. In all arrangements an ample supply of air is provided, and some means for preventing it from entering the tubes without having combined with the gas. As this is a matter which greatly affects the coal bill of a railway, it is well worth the careful attention of those in charge of such matters with us. The fire door is now always made sliding, and consists merely of two plates, connected by links in such a way that they open and shut together by a simple push with the foot on a suitable lever. Beside being much handier and more out of the way, they have the advantage of not being blown open in case of the failure of a tube. The usual size of blast pipe is four and a half inches or five inches, always single. English engineers deem it very important that the boiler should be subjected to no strain other than that arising from the pressure of the steam. Accordingly the cylinders are fastened to the frame alone, and all the working strains are sustained by the framing, the boiler being simply carried on it. The frames consist of deep plates, one inch thick, running the length of the engine, with jaws forged on, wide enough to receive the axle boxes, and in some cases made deep enough at the forward end to completely encircle the steam chest of an outside cylinder. (which is at the side of the cylinder, and projects inward through the frame,) and allow of a goodly number of bolts being put through the frame and casting. This form of frame is, no doubt, very rigid and good.

With inside cylinders the two steam chests are turned toward each other and bolted together, the cylinders being bolted to the two frames by flanges on their opposite sides. This is an exceedingly inconvenient arrangement for taking care of the valve seats, as there is but a narrow space for getting at them to scrape them if necessary, yet there is but one line, the London and Southwestern, that has adopted our plan of using a rock shaft, and placing the valve chest where it is accessible. In regard to valve motion there is much greater variety than with us, for while we have generally agreed upon the shifting link of the curved slotted form, with knuckled joints for the eccentric rods behind, here there is not only a division between the shifting and stationary links, but in regard to form and positions of the centres there is every possible variety. In addition to these there is a form of link which has been largely adopted of late, from the cheapness with which it can be made, which is a combination of the two systems, the link being straight, and therefore easy to fit up, and is suspended from a weigh shaft, which also carries at its opposite extremity the valve-rod link, so that when one is raised the other is lowered, and both move in the operation of reversing. This gives as good a distribution of the steam as the other forms, and in addition to its simplicity has the advantage of dispensing with the counterbalance, as the link and valve rod link counterbalance each other.

The reciprocating parts are now mostly made of Bessemer metal, to insure strength with lightness. The pistons are made in a much simpler manner than ours, and are equally good as regards tightness and smoothness of the cylinder. They are generally packed on Ramsbottom's patent, in which the piston is a light solid disk, with a flange to give width of bearing on the cylinder. In this flange are turned three square grooves five-sixteenths inch wide, and into these are spring rings of square steel wire of that size, cut carefully to exactly the proper length, so that the ends shall just come together when in working condition, having first been bent to the proper curve so that they shall be pressed out by their own elasticity to a steam-tight bearing. Nothing could be simpler or more efficient than this for a piston packing.

All locomotive wheels are of wrought iron, generally with steel tires. As already stated, the size of both driving and carrying wheels is larger than with us, and the same applies to the carriage wheels also, which gives an advantage in regard to ease of traction, at least where the roads are good enough, as they are here, to admit of them without danger of riding the rails."

DIVISION NINTH.

MARINE ENGINEERING.

57. *Types of Ships in the French Navy.*—From a very able paper in the "Engineer," under the title of "The French Naval Exhibits" at the Paris Exhibition, we extract the following:—"Three great types of shipping characterise the French navy, as evidenced by the very instructive set of models of war ships exhibited by the Ministry of Marine in the great zone of the main building. These may be classified, roughly, as—1, the floating iron-plated battery, for coast defence, &c.; 2, the heavy armour-clad ship of the line, whether broadside or turret; 3, the swift corvette, or *aviso.* Between, or perhaps in addition to these classes—completing our classification, arrived at, so to say, ethnologically at the commencement—are the yacht and the war transport for the conveyance of troops, which latter is dividable into the transport for infantry and material, and that for cavalry, artillery, and horses—the '*transport ecurie.*' These models are all to a large scale, and are typical in almost every instance.

Amongst the floating batteries is found the *Garde Cote*, of the Belier type, a model to a scale of 3 centimetres per metre—about 5 ft. 9 in. over all, by 21 in. in width—a nearly completely covered in, flat-bottomed, round-bilged, and tumbling-in sided ship, of 530-horse power, executed at Brest; a very powerful ship for defence beyond question. She has a sharp under-water beak forward, plated and sloped back without break of any sort, up to a cylindric turret, placed well forward, and mounting two heavy guns, without revolving at all. Astern of this, and only about equal breadth athwartship, is the only exposed deck, with high plated bulwark and hammock nettings above; through this the low funnels rise, and the only approach to this deck is from a ladder over the side. Beneath it is one large well-ventilated deck for the crew. The stern is a blunt sort of beak shape—though not a beak. There are twin-screws, and the rudder is handled from the lower deck. This ship is intended always to be fought stem on towards the enemy; and the twin screws, giving great facility of turning, afford the means of dispensing with any revolving of the turret or guns. As a roadstead or harbour ship. never going out of her own waters, the twin screws are not liable to entanglement by floating objects, unless, indeed, such could by some chance be caused to drift down upon her, or be towed by two enemy's ships up to her—both unlikely conditions. There is no top hamper, nor any rigging whatever—nothing over deck but the funnels, and these to about half their low height, as well as the deck itself generally, are greatly protected by the turret as by a breastwork, so long as the ship can be kept stem on to the enemy. This type, it appears to us, admits of being improved and developed into one of the most formidable, handy, and cheap sorts of floating battery and ram for harbour and cost defence.

Amongst the other models of floating batteries shown, are the Arrogant, a flat-bottomed plated battery, with a central flat-sided iron bastion, pierced for ten or more guns, and with a short deck at either projecting end, the ends being sloped upward; propulsion is by screw, the funnel rising through the centre of the bastion and above it. This seems to us about the worst example of any type shown.

The Embuscade forms a third and very singular, and—to our view—injudicious type of floating battery. She is a very short, stumpy, flat-bottomed ship; wall-sided, and wedge-shaped stem, with cutwater perfectly vertical, and with the stern cut away sloping under water, for twin screws. She is very short, not more than about three breadths in length, is plated all over, and pierced for seven guns at each side. The funnel rises above the deck, which appears to be plated under the planking, and there are two spars for some sort of sails, which look useless enough.

The ships of the line, if we may keep to that old phrase, exhibited are La Gloire, La Flandre, and La Solferino, which are all broadside ships, as is well known, and have been before described by us, and elsewhere. With these is shown the Marengo, a ship with a plated midship bastion or battery between decks, and with four revolving turrets. The chief noticeable points in these ships in relation to their order of date of construction are, increase of size, some modifications as to lines, and increased weight of armament. There is little to remark on as constituting any positive improvement in the working out of the problem of the wished-for invulnerability which, for ships destined to hold the seas, will one day or other be admitted to be as mere an incumbrance as the plate-armour of the fourteenth century was to the horseman. Let the naval architect do what he can, with anything but an air-tight cancellated ship, which, if it is to have a crew, is an impracticability—the victory must ever remain with the gun, not with the plated ship's side, or even the turret. If so, the more iron with which the ship is loaded, only the more swift and unforeseeable must become her destruction when exposed to adequate cannonade.

By far the most formidable and mischievous-looking ships exhibited by the French marine, in our eyes, are their swift and large dispatch boats, or *avisos*. Of these they show four different types, viz. :—1. The *aviso* of the type of the Infernal. These are ships of iron, with lines almost as long, fine, and swift as those of a yacht, three masted, square rigged, with one funnel and one screw, driven by engines of 450 nominal power, and provided with ports for ten heavy guns, all upon the upper deck. 2. The *aviso* of the type D'Estrées, much like the last in all respects, but smaller, intended for five heavy guns, all rifled, and with 250 nominal power, one screw. 3. The *aviso* of the type Bouvet, still smaller than the last, lighter rig, one screw, 150 horse-power nominal, and for three guns, one only of which is a heavy pivot gun. 4. The *aviso* of the type of the Imperial yacht Jerome Napoleon, which is scarcely other than a smaller and rather finer lined edition of the second and third types. Nothing can exceed the beauty of the lines of the first and largest type of these swift ships, and the skill is great with which the maximum of speed, the power of keeping that up for a long period under all conditions, and the power of a heavy battery have been here combined. We speak upon a nautical question with the reserve and modesty that would always become landsmen, but the impression is strong with us that the opinion uttered by many competent men is not far wrong, namely, that a squadron of these great, fast, handy, heavy-armed ships, without any armour plating of any sort to encumber them, would prove quite a match for any nearly equal number of heavy, lumbering broadside or turret ironclads, and that for almost every purpose of offence of which a ship is capable, they would prove themselves the most destructive possible class of ships of war. They are, in fact, the application, to iron hulls, steam propulsion, and rifled ordnance, of the principle (if we may call it such) of the great, fast, heavy-armed so-called frigates of the last American war with Great Britain—frigates that were intended to combine the size and power of the then ship-of-the-line, with the speed of the ancient frigate of the days of the Canopus.

Much of what such ships as these could or could not effect against ironclads, or in other cases or occasions, would no doubt depend on the daring and nautical skill of those who handled them. It is for this very reason, and because we believe that neither the skill nor the indomitable pluck of 'the old sea dogs' of our naval annals are extinct amongst us, and because in these characteristics our seamen assuredly proved superior in past days to those of every other nation, that we think ships of this type might prove, in our hands, the best possible match for whatever is likely to be brought against us on the high seas.

This is a question, however, upon which much may be said on different sides, and is of a class upon which at present, and in the absence of any sufficient data from actual warfare, even the experienced seaman will be reserved, in proportion as his opinion is of weight and worth having.

There are two types of transport ships shown, both of which seem to possess much merit in general construction and in details of arrangement, for ensuring the safe and rapid shipment and disembarkation of troops and stores, etc., and for the comfort and health of large bodies of men in long voyages.

The first is the *transport écurie* of the type Creuse. She is a huge ship, with two decks under cover, fitted for troops, three masts, square rig, one double-bladed screw (upon the peculiar French design), driven by 430-horse power nominal, and one funnel. Her lines are finer than those of the armour-clads, but not so fine as those of the *avisos.* She carries four guns only, and is provided with seven boats and iron launches. It would be impossible, in the absence of detailed drawings of every deck, to describe the arrangements for the stowage, &c., of the horses, men, and stores.

The other type of transport is that of La Cher; generally like the last, but smaller, though still three-masted, with 150-horse power nominal, and one double bladed screw. These vessels carry five guns, but of a smaller nature than in the ships of La Creuse type.

The safety and general health with which the French brought home their army from Mexico is the best comment upon the excellence of their arrangements of transport ships. A form of transports for cavalry and artillery seen by us at Cherbourg two years ago—and whose aim seemed to be the power of rapidly throwing such forces upon a neighbouring coast should occasion arise—does not seem to be exhibited at Paris."—*Engineer*, Aug. 9th, 1867.

58. *Admiral Halsted's Ships of War.*—We take from "Engineering," under date May 17th, 1867, the following:—"The proper construction of ships of war is a question as interesting in Paris as it is in London, and various plans have been propounded here as elsewhere for the construction of the fleet of the future. One of these projects is that of Admiral Halsted, which has already been, to some extent, described in our pages, and which consists in the use of certain classes of turret vessels, on Captain Coles's plan, but so systematised as to be appropriate for vessels of every different size and armament. Ten models of war ships, designed by Mr. C. F. Henwood, so as to embody Admiral Halsted's ideas, have within the last few days been added to the Exhibition by Messrs. Napier and Sons, of Glasgow, by whom the models are exhibited; and these models, which are admirably formed and finished, pretty fully illustrate Admiral Halsted's ideas. In one respect we approve his project, namely, that he does not profess to protect the whole side, but only a belt at the water-line, so that practically his vessels are monitors, with tall turrets, and raised upon by means of tall unarmoured sides, which will give useful accommodation during peace, but which accommodation may be vacated on the incidence of war. Undoubtedly all this is a step in the right direction. But it would be a still greater step if Admiral Halsted would disencumber himself of his heavy rigging and high sides, and make a vessel suited for actual war to begin with. Admiral Halsted says that his system is founded upon the four following propositions: 1st. As in past battles between fleets of wood, so in future fights between iron-

clads the respective projectiles must determine the issue of victory or defeat. 2d. The respective projectiles must determine this issue, according to their excellence in material, proportions, form, range, accuracy, penetration, and explosive force. 3d. These requisite conditions of excellence in the projectiles must govern the conditions of the gun. 4th. The requisite conditions of the guns must govern the mode of ship best able to carry and fight them. Now we humbly suggest that, in propounding these main propositions as the basis on which our future ships of war must be constructed, Admiral Halsted has left half of the question out, since it is not only necessary that we should be able to damage the enemy, but that we should be exempt from damage ourselves. This end is only to be attained by carrying very thick armour, which is only to be carried on the monitor plan; so that, for real fighting ships, to the monitor plan we must finally come. We suppose Admiral Halsted's propositions mean to imply that heavy guns can only be carried in turrets. But this is quite a mistake, though we concur with Admiral Halsted in thinking that they can be more conveniently carried in turrets than in broadsides. The question, however, is one merely of convenience, and not of practicability, and must not be pressed to such lengths that the statement becomes inaccurate altogether. Admiral Halsted describes the future of his system as follows: '1. The ratio of length to breadth is alike in all except in Nos. 6 and 8, in which that ratio is greater. 2. All have one character of form, with steam power calculated for 14 knots speed, except Nos. 6 and 8, which are calculated for 15 knots. 3. All carry the same full proportion of fuel per nominal horse power of engines, thus providing a common steam endurance for combined operations. But No. 8, as an 'Ocean Despatch,' carries a still larger proportion as a supply for frequent chasing, and for steaming at full speed 5,000 miles. Nos. 6 and 8 are especially designed for the protection of commerce. 4. All carry, upon the ordinary three masts, the full sail power of former frigates, thus providing for all sail manœuvres and operations at highest sail speed. The masts, spars, sails, fore, main, and mizen, are alike in each ship, and largely interchangeable throughout all classes. 5. The mode of rudder provides ample steerage power under steam for the safe and uniform evolutions of a fleet. 6. All turrets are alike, and armour and backing are uniform in all classes. The patent metallic backing of Mr. John Hughes is adopted in ships and turrets. 7. The turrets and their guns will work with steam power calculated for two rounds per gun per minute, and manual power is provided as a reserve. 8. All have complete spar-decks for working the ships under sail only, without impeding the fire of the turrets. 9. All guns, including boats' howitzers, are Whitworth's polygonal rifles; the carriages are Captain T. B. Heathorn's, R.A., on his patent plan of muzzle-pivots. 10. The boat equipment is more complete and far superior to any hitherto supplied. It includes collapsible lifeboats, by the Reverend E. L. Berthon, M.A., for troops and general service, as with former paddle-box boats. Steam is provided for launches, pinnaces, and cutters. 11. The freeboard admits of steaming 'head to wind,' and the fire of the turrets will be equally unimpeded in almost any weather. 12. The draught of water does not exceed that of present ironclads. In this adaptation of Captain Coles's turret system, it is added the main and lower decks are available throughout for the accommodation of officers, crew, and troops, with light and ventilation as ample as any in past description of war-ship or transport.'"

59. *On a New System of Hydraulic Propulsion.*—The following paper was read by Captain E. H. Simpson, R.N., before the Royal United Service Institution, June 24th, 1867 :—"Having for many years experienced the practical defects in the screw and paddle, as propellers for Her Majesty's ships, it occurred to me that an internal propeller, or some mode of driving the water through the vessel in a continuous stream, might be applied with advantage. This being the case, it may occur to many that my ideas were realised in the hydraulic propeller as patented by Mr. Ruthven; this, however, was not so. I have studied Mr. Ruthven's plan with great attention, and, for reasons which I purpose presently to explain, rejected it. I therefore followed out my own ideas, which resulted in the following plan :—

A hollow cylinder or drum closely fitted in a casing, but with sufficient room to revolve freely therein, is mounted on an axis by which it is driven in the manner of a paddle-wheel. The hollow drum is furnished with a number of slits or casings disposed radially and open at the circumference. In these casings, which each extend the length of the cylinder, are fitted pallet or float boards, by which the propulsion is effected. These floats slide in a radial direction, and are capable of projection beyond the periphery of the cylinder to an extent to offer the requisite amount of surface to the water for propulsion.

The position of the floats is controlled and regulated by pins or studs, with or without friction rollers, projected from each end of the floats. The pins or studs travel in cam grooves in the outer casing, so arranged as to project or withdraw the floats during the proper periods in the revolution of the drum or wheel. The case containing the drum or wheel has an arc or section removed at the part where the floats are projected from the drum. This opening in the case may either be united with a channel passing through the body of the ship, or it may be united with the sides or bottom of the ship, so that the floats, when so projected, pass into and operate on the external water.

This wheel or drum being hollow, and wholly or almost wholly below the water level, will, by its buoyancy, relieve the bearings of weight and friction.

When, in order not to interfere with the sailing qualities of the ship, it is desirable to withdraw the whole of the floats within the periphery of the wheel, it is simply necessary, by means of points somewhat similar to those used on a railway, to alter the course of the cam grooves in the outer casing. This casing is of course water-tight, and is, if necessary, fitted with a semicircular slide, which, when the floats are turned off within the barrel, is closed, thus shutting off all communication with the outer water, and enabling repairs, &c., to be carried on in any weather.

It will be observed that my invention of the sliding float, worked by a stationary cam groove, could be applied so as to drive the water in any direction in a continuous stream through the vessel without check, and was also applicable for external propulsion.

It became an interesting question to ascertain which of these two modes of application would be preferable.

I therefore fitted a small boat, about 7 ft. long and 18 in. beam, with my propeller, with the floats projecting through the bottom of the boat and acting on the external water. The motive power used to drive the propeller was a powerful piece of clockwork.

The boat was then placed in the water with her stern against the bank, and the clockwork being wound up, it was started, and the time accurately noted that was taken to unwind five turns of the spring, which was invariably 70 sec. after. This was done repeatedly, and not a second's variation in the time observable; the boat was taken out of the water, and a false bottom, of about 18 in. in length, fitted over the floats, thus making a clear straight passage open fore and aft, of a size corresponding to the full projection of the float. The boat was then placed in the water as before, and the clockwork started, when the five turns of the spring were invariably unwound in 55 sec., thus practically showing the greatly superior resistance offered to the action of the floats by the external water to that offered by water in a tube or passage, the cause of this difference being, I believe, due to the fact that in the tube or passage an area of float board equal to only one whole float meets with any resistance at one time, whilst, in the case of the propeller acting on the external water, the whole area of float board projected bears a portion of the resistance felt, and that as the velocity of the vessel through the water is increased, so will the resistance on the whole of this area approximate more nearly to the theoretical resistance. And hence I argue that, the size of the propellers and their floats being equal, that the propeller acting on the external water must give a far higher speed with a given power than the propeller acting in the through passage.

I should now like to say a few words on the hydraulic mode of propulsion, on account of the intimate connection it has with the ideas and experiments I have been endeavouring to describe to you.

It is in fact an internal propeller of somewhat different form from mine 'when working in the through passage,' but dependent for its propelling power on similar principles, viz., the reaction due to water discharged at a given velocity. For instance, supposing I were to block up my water passage before and abaft the propeller, and to introduce tubes so as to bring the water in and carry it out or discharge it through the sides of the vessel, I have only to fit the nozzles on the end of the discharge pipes, and I have the hydraulic propeller—not the turbine wheel, but the hydraulic propeller.

The question arises, which is the most convenient form of application—to use the straight passage, and thus to communicate the pressure due to the reaction of the water directly through the float to the vessel, or, by making the water take an indirect course, cause the pressure due to its reaction to be felt at the back of the discharge pipes?

Now if we put the question of friction on one side, and suppose two similar vessels of the same engine power fitted with propellers, one on each of these plans, we should find that as long as the vessels were stationary that each would drive out or discharge the same weight or quantity of water, but when we come to compare the action of the two plans with the vessels in motion, we shall see a great difference. For instance, suppose the vessel with the straight through passage to be moving at the rate of nine knots, or 15 ft. per second, through the water, as there is no friction the water will flow through the passage of its own accord at that rate, and the floats of the propeller would have to travel at that velocity, and the velocity necessary to accumulate upon them a pressure or resistance equal to the moment of resistance of the ship—as is the case with the ordinary paddle-wheel—if we suppose this to be 7½ ft. per second, the power used will be that of a weight equal to the moment of resistance of the ship, moved with a velocity of 22½ ft. per second.

But with the hydraulic propeller this is very different. The water discharged, and its consequent reaction at the back of the discharge pipes, will be the same whether the vessel be at rest or moving through the water; and consequently, if her discharge pipes are equal in area to the float surface, and no other retarding force peculiar to the plan were brought into play, the power required to propel her 15 ft. per second would be only that of a weight equal to the moment of resistance of the ship for that speed, moved with the velocity of 7½ ft. per second, or one-third of the power required in the other vessel. But there is, I believe, a most important retarding force brought into play, and I believe it to be this: The water that is taken into the vessel when she is in motion is taken from a state of rest, and is not only driven through the tubes and passages by the engine, but is also carried forward by the ship, and consequently the momentum of the ship is destroyed by a force equal to that required to move the quantity of water taken in in a given time, a velocity equal to that of the ship's motion, and consequently that water must be discharged in the opposite direction with a similar velocity before its reaction at the back of the discharge-pipes will counterbalance this loss, and the excess of the velocity at which the water is driven through the discharge-pipes over that of the ship is alone available for propulsion, or, in other words, for overcoming the moment of resistance of the ship; and it is evident, according to this principle, that in order to get an available pressure at the back of the discharge-pipes equal to the moment of resistance of the ship, that the engine must be sufficiently powerful to drive the water through the discharge pipes with the velocity of the ship and the velocity necessary to accumulate that additional resistance. And the remarkable power displayed by vessels propelled on this principle of starting ahead and stopping are, I believe, due to the same cause, viz., the necessity entailed on the vessel of giving a velocity equal to her own to the water used for propulsion.

I therefore, for the reasons I have endeavoured to make clear, conclude that for an internal propeller the direct passage is greatly preferable in point of speed, but that the hydraulic principle, in proportion to its sacrifice in this respect, obtains a distinct, and in some cases valuable, manœuvring power; but I have before stated that all internal propellers of equal size with external ones must fail in the primary object of speed, and therefore the best propeller will be the one that combines within itself the good qualities of both internal and external systems, and this is the principle upon which my propeller is constructed. It has the advantages of the internal propeller in its freedom from fouling from spars or rigging shot away in action, and from injury by an enemy's shot, &c. It gives superior manœuvring power to any other mode of propulsion, for it equals the screw in rudder power; the water being thrown by the floats directly upon the rudder, it pivots the vessel on her centre, if her wheels are used and made to revolve in opposite directions, and is capable of propelling the vessel either end first with equal speed and facility.

It is superior to the screw as a submerged propeller, it being impossible under any circumstances for the motion of the ship, whether by pitching or rolling, to interfere in the least with its direct and steady action.

It is equal to the eccentric paddle-wheel in the directness of the action of the floats, but greatly superior to either radial or eccentric paddle in its steady and invariable immersion and freedom from vibration, the floats never striking or lifting the water, but sliding gradually though rapidly in and out of it.

And lastly, it is superior to either screw or paddle in the comparatively undisturbed and unyielding water that it is enabled by its position and superior immersion to act upon.

In the competitive trials on a small scale between the ordinary radial paddle-wheel and my propeller, the immersed float area and speed being equal, the power used by the ordinary paddle-wheel was as seven to five used by my propeller—the slip of paddle-wheel being 40 per cent., of my propeller 17 per cent."

DIVISION TENTH.

AGRICULTURAL MACHINERY IN THE PARIS EXHIBITION, 1867.

66. We contributed the following paper to the "Agricultural Gazette," and we now re-produce it here. "We begin by taking as first in point of the direct interest it has for our readers, if not, indeed, for the high class of the work displayed in it, the Annexe containing the examples of agricultural machinery exhibited by *British* manufacturers in the Annexe in the Park at the side nearest the Seine, and commencing at the end next the Railway Station of the Chemin de Fer Ceinture (the railway which encircles Paris, and a branch of which runs into the Exhibition, ending on the one side of Paris in the Avenue de Clichy and on the other at the Station St. Lazare, near the Madelaine).

At this end of the Annexe Messrs. Barrow & Carmichael, of Banbury, have their stand, and exhibit a specimen of their 8 horse-power portable steam engine for agricultural purposes, the cylinder being in the centre of the boiler, and outside. Near to the engine there is a stand containing a number of specimens of different sizes of the 'Needle Lubricator,' or Lieuvain's Patent, and the English agents of which, Messrs. Clarke & Dunham, 48, Mark Lane, London. This is a very simple form of lubricator, by no means easily got out of repair, and its use results in a very large saving of oil.

Next to the specimens of these lubricators are examples of flour-dressing machine brushes and millstones, exhibited also by Messrs. Clarke & Dunham. The next stand to be noticed is that of Mr. Underhill, of Newport, who exhibits as his principal article a specimen of his traction engine. In this the driving wheels have their tires made in zig-zag fashion ⋞, the object of this arrangement being to enable the tires to take a bite of the ground over which they are passing, and enable them to pass over heavy land; the soil pressing into the corners of the zig-zag give a hold to the wheel. The steering gear is worked from behind, a place at the side of the firing end of the boiler being appropriated to the steersman. We might here point out some details of this engine which we think could be improved both in point of arrangement and construction. Mr. Underhill also exhibits a horse hay rake, in which a balance or counterpoise weight is employed to ease the lifting and working of the levers when the tines are filled, and their load is to be released. Next to the stand of Mr. Underhill is that of Mr. William Newsham Nicholson, of Newark-upon-Trent, who exhibits specimens of corn-weighing and sack-lifting apparatus, oil-cake breakers, and a specimen of his hay tedding machine. We have so often had occasion to make favourable remarks, both upon the arrangement and construction of the machines of Mr. Nicholson, that we pass on, simply pointing out their locality to the notice of the visitor.

Opposite the exhibits of Mr. Nicholson, T. A. Brae & Co., of Ludlow, show a small grinding mill, in which, in place of the usual steel and iron cone and grinding surface, the grinding surface and cone are made of the usual millstone; the arrangement for working the mill is simple. The portable engine next to this stand, which is exhibited by Messrs. Fox, Walker, & Co., of the Atlas Iron Works, Bristol, is characterised by its sound workmanship and its good arrangement; it is a double cylinder engine with outside cylinders. On the other side of the main alley of the Annexe, opposite to the above engine, are the articles exhibited by Messrs. Wallis, Haslam, & Co., of Basingstoke, and which consist of examples of their portable horse power threshing machine and driving gear. By a judicious arrangement of the parts the carriage, which when the apparatus is at work forms the framing of the horse driving gear, carries the threshing machine, so that the whole can be transported from place to place. We next come to the articles exhibited by Messrs. Ashby and Jeffery, of Stamford, and which consist of specimens of their well-known horse hay rakes, hay tedding machines, and straw cutters.

Opposite, Messrs. Robey & Co., exhibit a specimen of their threshing machine for power, with portable steam engine, both of which, in point of workmanship and arrangement, will sustain the high reputation this firm has already achieved for work in this department of agricultural engineering. Opposite these machines, Mr. Freer, of Rothley, near Loughborough, exhibits a specimen of his corn dibbling machine. This is somewhat complicated in arrangement, yet works easily and deposits the seed at intervals in any quantity desired. The main feature of the machine is the employment of hollow disc wheels, in the interior of which are a number of passages which communicate with the receptacle above containing the corn to be dibbled, and with apertures at the periphery of the wheel, and which apertures are closed and opened at regular intervals by means of iron bolts or studs worked by levers, which receive their motion by the revolution of the wheel as the machine progresses. Each machine is provided with two of these hollow wheels placed at a certain distance apart on the central axis, so that two rows of dibbled corn are put in at the same time. By no means desirous to discourage any inventor, on the contrary, believing that Mr. Freer has made an important step towards the solution of the problem involved in the bringing out of a corn dibbling machine, we nevertheless think that there is yet much to be done before a good and a cheap machine is produced. In the growing liking for their sowing, there is much reason to urge upon inventors the necessity of bringing out a machine capable of doing this work cheaply and well.

Mr. Bamlett, of Thirsk, Yorkshire, exhibits specimens of his now well-known reaper; Messrs. Brown and May, of Devizes, a specimen of their threshing machine, with portable steam engine; Messrs. Whitwell & Co., of London, specimens of their hand-power corn-grinding mills; Messrs. E. and G. Turner, of Ipswich, specimens of their well-known seed-crushers, oil-cake breakers, and portable steam engine; Messrs. Riches & Watt, Duke's Place Iron Works, Norwich, specimens of some oil-cake breakers, and flour grinding mills; and Mr. Sheen, Aylesbury, Bucks, specimens of chaff-cutters; all of these stands being near each other.

The stand of the Reading Iron Company (late Barrett, Exall and Andrewes) does not comprise many articles, but what are shown are of a character in every way worthy of the reputation which the firm has for sending out first-class work. We would draw special attention to the horizontal steam engine of 12-horse power. This engine is fitted with expansive gearing—cut off, or degree of expansion, being regulated by a very simple arrangement of hand. wheel, and graduated index; by turning the wheel the valve which regulates the degree of cut off is adjusted; and one feature is that this can be done without stopping the engine, so that according to the wishes of the engineer any amount of expansion can be given during the working of the engine. The cylinder of this engine is steam-jacketed, which still further economises the use of steam. The same firm exhibit a specimen of an 8-horse portable steam engine, which is provided with a water-heater. The water to supply the boiler is passed through a range of pipes placed in the smoke-box before it is passed into the boiler; a portion of the heat which would otherwise be wasted and passed up the chimney is thus economised. In consequence of the position of the engine, close up against the wall, we could not get the smoke-box door opened to examine this form of water-heater, but from the explanation we received of it, we do not think it will be so efficient as the plan proposed by Mr. Brown some years ago, of encasing the whole of the smoke-box with a wrought-iron case, the water being admitted into the space between the smoke-box and this case, heated, and from thence passed into the boiler. Those who have felt the temperature of the smoke-box ends of portable engines while in full work must have been convinced of this, that a large amount of heat was being wasted. We have yet a vast deal to do in the economisation of the waste heat evolved in the working of our steam engine furnaces. There are one or two points of construction in this portable engine exhibited by the Reading Iron Company worth of notice here. The crank shaft is supported in pretty high bearings, and these are capable of being adjusted vertically or laterally by appropriately placed set screws. To give a certain degree of lateral play to the crank shaft, and thus prevent the chance of its being broken—a contingency to which all shafts are more or less subjected—the shaft from the fly-wheel has no collars or ruffs on it, and only one collar or ruff is given to the end of the shaft opposite to this; under certain circumstances of extra strain, therefore, the shaft, by the lateral movement which is permitted to it, can give and take, so to speak, within a certain limit of range. The same firm exhibit also specimens of their well-known "horse gears;" the whole of the working parts of which are enclosed in an elegant iron case. The upper part of this case revolves with the action of the horses, and the annular wheel with which its interior is provided gears with three equal diametered spur wheels, from which the power to drive the machine is taken by appropriate means. A specimen of their circular saw bench, of their hay-tedders, straw-cutters, and very beautifully executed models, are also exhibited by the firm.

Opposite the stand of the Reading Iron Company, Mr. Kearsley, of North Street, Ripon, exhibits his reaping machines, and Mr. Hartley, of Otley Mills, Yorkshire, his corn cleaning machine. This apparatus consists of a vertical cylindrical case, in the interior of which is a central shaft, carrying inverted cones of plain and perforated surfaced iron, these being surrounded with a perforated casing nearly in contact with the cones; a pair of fanners is placed in proper position, and in connection with the interior of the case. The corn to be cleaned is poured into the cylindrical case at the upper part, and in falling down is caught up by the revolving cones, and the smut, &c., rubbed off by coming in contact with them and with the outer perforated case, which is finally taken off by the power of the blast, the cleaned corn falling into a receptacle provided for the purpose of receiving it.

Next to the stand of the Reading Iron Company, and on the same side of the Annexe shed is that of Messrs. Fowler & Co., of Leeds, the main feature—and it is one worthy of the high position which English agricultural machinery occupies in this Exhibition—of which is the steam cultivating engine with clip drum and traction gearing. The arrangement and workmanship of this splendid machine is worthy of any of our high-class locomotive engine factories, and in saying this we can give no higher praise. In addition to this engine, Messrs. Fowler and Co. exhibit specimens of their balance plough and self-acting anchor, together with various parts of their ploughing apparatus; and some very beautiful photographs of the whole at work, as well as one of their newly introduced steam cranes, to which branch of mechanism the firm is, we believe, devoting some attention.

Opposite to the stand of Messrs. Sadler & Co., of Leeds, Mr. Tye, of Lincoln, exhibits a very well arranged and excellently constructed corn mill, with adjustible step, and his well-known corn dressing machine. Next to the stand of Mr. Tye is that of Messrs. Richmond and Chandler, of Salford, Manchester, in which there is a good number of the machines for which this firm has been so long and is still celebrated, as their straw cutters, oil-cake breakers, and their horse gears. Their straw cutters are, as we have often had occasion to remark, distinguished not only by neatness of design but superior excellence of finish. In this class of machinery they have recently introduced a very simple form of gear, by which the length of the cut can be altered with great ease. Opposite to the stand of Messrs. Richmond & Chandler is that of Messrs. Marshall, Son & Co., of Gainsborough, who exhibit a threshing machine for power, with a portable single-cylinder steam engine; a very tiny, neatly-made horizontal engine, together with a vertical engine with a somewhat peculiar arrangement of the cylinder. The firm also exhibits a good collection of photographs.

We now come to the stand of the Messrs. Ransome & Sims, of Ipswich, whose collection of implements and machinery, if not the largest—which we incline to think it is—is one of the largest displays in the British department. In this collection there is a fine display of ploughs of different kinds, threshing machines, portable steam engines, oil-cake breakers, corn-dressing machines, &c. They also exhibit a fine specimen of their recently introduced traction engine, which presents some features worthy of notice by the observant visitor. The steersman stands on the foot-plate of the engine, alongside of the engine-man, who works the engine; the supply of water is contained in a tank underneath the boiler, and is calculated to contain a supply equal the wants of the engine for a travelling distance of 10 to 12 kilos. The engine is single-cylindered, and provided with reversing gear. Opposite to the stand of Messrs. Ransome & Sims is that of Mr. Smith of Kettering, who shows a collection of the horse hoes for which he is so well and so favourably known. Hill and Smith, of Brierly, Staffordshire, display on their stand next to this a collection of hurdles, sheep racks, root cleaners, and straw cutters. Going now to the opposite side of the alley, next to the stand of Messrs. Ransome & Sims is that of Messrs. Clayton, Shuttleworth & Co., who exhibit an excellent selection from the implements and machines for which they are so celebrated. We would draw especial attention to the example of a horizontal steam-engine which they exhibit, which shows not only in the design, but in the execution, a knowledge and workmanlike care which would be creditable to the finest locomotive or engine work in the kingdom. The truth is, the workmanship is so superior, that, recollecting the too numerous examples of the excessive carelessness shown by farmers and farm servants in steam machinery which we have met with, we fear this style of work is far too good. How is it, we may here ask, that in nearly every other trade in which steam power is employed, a certain degree of pride is always taken to keep the engine, not only in good working order, but in perfect cleanliness, while on farms a state of matters prevails in this respect about which the less is said the better—unless, indeed, we do say what can only in the great majority of instances be said, namely, that it is not creditable to any one concerned in its maintenance? Farmers little know the loss they sustain by allowing expensive machinery to be in a chronic condition of dirt and neglect.

The stand of Messrs. Hornsby & Sons, of Grantham, is made up of examples of threshing machines, portable engines, straw cutters, corn drills, and a reaping machine, with self-acting gatherer. Opposite this stand is the collection of Woods & Cocksedge, immediately above which, on the same side, Mr. Neighbour displays examples of his well-known bee hive. The collection on the stand of Messrs. Woods & Cocksedge, above alluded to, is made up of horse-power threshing machine, with the driving gear for the same; oil-cake breakers, root cutters, corn bruisers, straw cutters, &c. And on the opposite side, next to the stand of Messrs. Hornsby, is that of Mr. Bentall, of Heybridge, who exhibits a somewhat extensive collection of his machines so well known in the trade, such as his root pulpers, oil-cake breakers, &c. The stand of Messrs. Amies, Barford, & Co., of Peterborough, comes next, and is occupied by examples of corn mills, land rollers, the weight of which is increased by the addition of water placed within the roller; examples of their well-known form of cattle food cooking apparatus are also exhibited. Next to their stand are examples of stable fittings, exhibited by the St. Pancras Iron Company. On another side is a rather rude timber construction, exemplifying the mode of erecting water-closets on the "dry system," by which a manure is directly obtained. This is made, not under Mr. Moule's patent, but under that of Mr. F. Taylor, who is assisted by the British Guano Company (Limited)—a company of the existence of which, in these days of unlimited examples of companies, we were not aware. We purpose in a future article taking up the department of social economics, under which this peculiar form of closet comes, and shall then explain its features, and those of other modes exemplified in this Great Exhibition. Next to this apparatus two stands are devoted to the display of specimens of manures, exhibited by Messrs. M'Clean & Hope, of Edinburgh and Leith, and by Edward Packard & Co. Interesting in some respects as these are, we cannot conceive that they will be of much practical interest to the agriculturist. Mere collections of manures, as manures, and of the materials, natural or artificial, of which they are composed, teach nothing; they may be seen, handled—and these, we have to say, may be perceived by another sense than those named—and their prices may be asked and given; but what they are really worth in the farmers' own special case of soil, locality, and climate, he cannot tell till he tries them; and even then he is not always altogether sure as to their value. To mere collections of manures we attach little practical value, nor is the case much improved if specimens of farm produce grown by their aid are shown along with them, unless every detail is given at the same time, all results of cultivation without their aid as well as with it; all of which details are not given—at least are not as a rule given.

Next to the exhibits of the St. Pancras Iron Company, thor of Mr. Samuelson, of Banbury, are met with, comprising his self-acting reaper, oil-cake breakers, root cutters, &c. The stand next in order is occupied by Messrs. Coleman & Morton, who exhibit their well-known cultivators with lever movements, also horse gears and oil-cake breakers. Then comes the fine collection and the very handsome stand and offices of the well-known Howard, of Bedford. A feature of the collection here to be met with is the display of neatly-executed models of nine steam-cultivating apparatus, &c. In addition, examples of their world-wide-famed ploughs are displayed, as well as of harrows, haymaking machines, &c. One point attracted our attention which, though apparently a small matter, is worth naming, namely, the very tasteful way in which this firm paint their machines and implements. The remark, however, applies also to other leading makers. There is none of the gaudy bizarre effect produced by the wretched display of brilliant colours which some makers affect, all which to our mind detract from rather than add to the taking appearance of the object so coloured and bedizened, and which are in every sense glaring examples of bad taste. Opposite the stand of the Messrs. Howard is a fine specimen of Aveling & Porter's traction engine, next to which is the shed of Messrs. Goulding, of Dublin, who exhibit a collection of their manures; and next to these is the stand of Messrs. Sutton & Sons, who show a collection of seeds. On the opposite side, and next to the stand of the Messrs. Howard, is that of the Messrs. Ganett, of Saxmundham.

Commencing with the *foreign departments of the class of agricultural machinery*, we pass from the Annexe of the British Department into that of the American or United States; and here the first machine met with is a specimen of Ericsson's hot-air engine, which is designed to work Dovell's fog signal; but which, fortunately for the tympanum of the ears of passing visitors, is silent. These hot-air engines are very much used in the United States, and are well adapted for cases where but small power is required. They are easily set in work. The cylinder is placed horizontally, and the fire-box is placed at its outer end. The air to work the engine is heated by passing round the fire-box, being forced into the fire-box through the air-pump in the backward stroke of the engine. The air-pump is placed within the piston of the working cylinder, this being made on the trunk principle, to admit of the air-pump piston being placed within it. Both the piston of the working cylinder and that of the air-pump which it carries make their forward stroke simultaneously, and at the same speed; but in order to force the supply of air into the furnace to be heated for the forward stroke, the air-pump piston on its backward stroke is made to travel at a much higher speed than that of the working cylinder. This arrangement necessitates the use of a very heavy fly-wheel, in order to store up, so to say, as much force or working power as is necessary to carry, not only the working piston of the cylinder through the whole extent of its stroke, but also the air-pump in forcing its supply of air to the furnace. There is another hot-air engine in this annexe, invented by a Mr. Roper, which appears compact, but is of peculiarly rough workmanship. A good deal of attention is being paid just now to the subject of engines of this class, as they in many respects are well adapted for rural districts where work is frequently to be done in which the power of the engine is not required for a long period. The great difficulty in the bringing out an engine of this class has been the proper heating of the air; for when passed directly from the furnace in which it is heated it carried with it many of the solid products of combustion, which destroyed the working parts, and the great heat acted prejudicially on the valves; on the other hand, by heating the air in a separate chamber, which was in turn heated by a furnace, the great difficulty experienced was the heating of the air quickly enough. A form of hot-air engine in which all these defects are overcome, and which is also an invention of an American, Mr. Philander Shaw, will be found in daily work in a separate shed in the Park, not far from the famous—or infamous in point of design—English cottage.

The next machine met with in the American Annexe is M'Cormick's reaper, provided with an automatic sheaf delivery. Nearly opposite this is the stand of Messrs. Douglas, in which there is a pretty extensive collection of hydraulic apparatus. In many of the centrifugal pumps the arms work so freely or so loosely that they have to be driven at a very high speed in order to raise the water from anything like a fair depth. In Mr. Douglas's pump the arms as they revolve are kept perfectly packed, so that the water is lifted with comparative ease at slow speeds. The packing is secured by adopting a system of peculiar valves attached to the arms, and which are made to travel in a certain path by means of friction rollers and a covered or eccentric path. The Messrs. Douglas also exhibit various forms of hydraulic rams. Near the stand last described is a specimen of Ballard's hay-making machine. If we mistake not, this, or at least a machine very like it, was exhibited at one of our recent Royal Agricultural Society's shows. It represents a system of working which is much esteemed in many parts of the United States, but which is of little or no esteem here, namely, the substitution of a motion resembling the action of hand tedding with a fork for the circular motion adopted in all our hay-tedding machines. The forks or tines are precisely those of the double-tined hand fork in use with us; they are secured to the ends of bent levers, which are jointed at their extremities to the main frame of the machine, and the outer ends of which have a reciprocating up and down motion given to them by virtue of cranks and connecting rods. A very good imitation of the motion of hand-forking or tedding is thus secured, resulting in rapid lifting and tossing up of the grass. Near this machine is a collection of ploughs useful in American work, and also of hand tools, as hoes, in which there is a specimen of a hoe so constructed as to register the number of strokes which the workman makes with it during a given time—a Yankee notion which seems more injurious than likely to be useful. We fear the invention will not be appreciated with us. We have thus glanced at the leading features of the American Annexe, from which it will be seen that they are not by any means numerous. This, indeed, may be said of all the American departments, still it is only right to say that what is wanting in number and variety is made up in the practical nature of the machines and objects sent, and in the quality of the work.

Passing out from the American Annexe, and keeping the outer building wall of the Park to the right, we proceed to make its circuit, and in process of time came upon the *Russian department* of the Park, the most prominent features of which are the Russian stables, and the Russian cottage, on the left. Before, however, reaching the stables, which are in themselves a beautiful specimen of wood construction, and which are well worthy of inspection, both inside and out, a shed is met with containing specimens of carriages ; at the end of this is a compartment containing a small but interesting collection of Russian timber, bricks, drain tubes, &c. Opposite, or nearly opposite, is the 'Isba,' or Russian peasant's cottage, which should be visited, not only from the interesting nature of its contents generally, but from those in the ground apartment, which were specially interesting to those concerned with agriculture. We should note here the small threshing machine, with flat beaters. The horse-gear, or power, by which this is worked, presents, in its odd shape, a very marked contrast to the neat forms of apparatus which are known to the frequenters of our show-yards, and also to those of the French Department. The horse gear under notice looks very much like a bale of cotton in shape ; it is made of wrought-iron plates, the wheels are all inside of what we have called the bale, the power being taken from the side. There is also here a straw-cutting machine, to which we would draw the special attention of the visitor, on account of the neat way in which the timber framing is constructed, pointing as it does to the wretchedly clumsy form adopted by our makers wherever they use this material in the construction of their framings. The visitor should also examine a very ingenious potato-planter, a reaping machine, a corn drill with small ploughs to sow seed, all of which present contrasts to our machines in their classes more or less marked, and all of them suggestive.

Leaving the Russian cottage, and continuing our walk round the Park, still keeping its outer boundary to the right hand, we come to the *French Annexe*, or long line of sheds, containing a very large and interesting collection of machines and apparatus used in the arts and manufactures, of which the agricultural machines and implements form a large and important proportion. The part of the Annexe first reached is devoted to a good collection of agricultural machines, exhibited by Albarrets, and consisting of threshing machines, horizontal steam engines, root-cutters, &c. The same house exhibits a traction engine, which will be seen in the Park nearly opposite, but at some distance from the working-men's refreshment rooms or Omnibus Restaurant. Further on is the selection of implements and machines of Gerrard—amongst which is the portable engine, with a form of water-heater worth notice. The lower part of the smoke-box is surrounded with a wrought-iron receptacle, which comes up in the semi-diameter of the smoke-box, and is some 5 or 6 inches in width. This is filled with water, which becomes very rapidly heated by contact with the hot plates of the smoke-box. This water, as it becomes heated, is forced into the boiler by the pump, the water passing through a wide pipe through which also the blast pipe of the engine is passed. The heat, otherwise lost, is thus economised.

At the end of the first long Annexe or shed is a separate shed entirely appropriated to the machines of the well-known house of Cumming and Co., of Orleans, consisting of threshing machines, portable engines, and horse gears. Opposite this shed is the handsome building of the *Spanish Commission*, containing a very large and most interesting collection of food produce, timber, minerals, wines, oils, industrial plants, as flax, hemp, &c. There are also a few agricultural implements and machines, a variety of wine-presses, and a double force-pump. Outside the building the visitor will find a chain pump for working by hand, and another for horse or rather donkey power, the donkey who works it being the cynosure of a large and apparently much interested crowd which is generally found round it—a crowd, by the way, made up of that body (a very large one) of visitors to exhibitions who seem intensely interested in looking at and examining objects to be met with every day, but who are quite oblivious to those which are to be rarely seen.

Opposite the Spanish Annexe, and going the round of the Park, still keeping the boundary wall to the right hand, a large shed is met with in the *French Department*. This contains a very extensive collection of machines and apparatus used in the industrial arts, and a good many more or less connected with agriculture, such as beetroot-sugar apparatus, animal charcoal ditto, wine and other forms of presses, filters. There are several examples of corn-cleaning machines, amongst which the most remarkable is that of M. Josse, of Ormerson, Canton de Boissy, Saint Leger, Seine et Oise. It is not easy to describe this apparatus without the aid of diagrams, but the reader may form some idea of its form and action if he will suppose a triangular plane enclosed by sides, and the surface of which is filled with a series of triangular blocks, with spaces between each block, and placed in such a way that channels are formed between which the grain, admitted from a hopper appropriately placed, passes in a zigzag direction. The plane which supports these blocks is divided with a wire or perforated bottom, and a to-and-fro or vibrating motion is given to it by means of a crank and appropriate gearing. The action of this apparatus is simple in the extreme, and the grain, as it passes over the vibrating perforated surface, and as it is forced to take the zig-zag channel made by the triangular blocks, is cleansed from extraneous matter, and delivered finally at the apex of the vibrating plane. Many forms of this apparatus are employed in the Government works in France, and are said to give great satisfaction. Another form of corn-cleaning apparatus to be met with in this Annexe is the invention of M. Dufour. It resembles Ransomes and Sims' corn-dressing apparatus in general appearance; the revolving cylinder has a two-fold motion given to it,—first, a revolving or rotatory one, and second, a vibratory to-and-fro motion in the direction of its length; while the outside of the revolving vibrating screen is struck at intervals with a hammer on its outer surface, to insure seeds sticking in the meshes of the screen being removed.

Issuing from this Annexe, and still keeping the building well to the right, we come to the Omnibus Refreshment Room, opposite to which, and nearly all of them in the open air, is a very large collection of implements and machines, chiefly composed of ploughs, rollers, and the like, none of which call here for special description, but of many of which, nevertheless, it may be said that they are worthy of study, if not for the purpose of knowing what to copy, certainly for the purpose of knowing what to avoid. In a small covered shed in this place, Renaud, of Nantes, exhibits a specimen of a portable steam engine, and a horizontal ditto, the workmanship of both of which is very good. He also exhibits a threshing machine, of which the English visitor should 'take a note,' as something rather unlike what we are accustomed to look upon as the arrangements of a good threshing machine.

Approaching the main avenue, which leads from the entrance opposite the Ecole Militaire, and not far from the main building is the *Belgian Annexe.* This contains a fine collection of machinery,—as locomotives, paper-making machines, and tools,—amongst which there are a few agricultural implements and machines. A peculiar arrangement of boiler for cooking cattle forage should be examined; it is in a corner towards the left hand on entering. Outside, ranged along the side of the building next the Ecole Militaire, are a good number of implements—ploughs, cultivators, and the like. Crossing the avenue leading from the Ecole Militaire, passing the corner of the Belgian Fine Art Annexe, and through the arch of the Gate of Antwerp, the second Belgian Annexe is met with. This is easily known from its octagonal form and its conical roof. Amidst a very interesting collection of tools, machines, models, specimens of metals, coals, &c., there are a few agricultural implements, the most important of which are some flax-dressing and breaking machines, which have a high reputation in Belgium.

We have now gone the round of the Park, and taken up in succession the Annexes therein which contain either special collections of agricultural machines and implements, or have these placed amongst general machinery and tools. We have not, of course, in the foreign department, noticed all which may yet be met with, but we have drawn attention to the most important, and have in all cases at any rate pointed out to the visitor, or intending visitor, the *locales* where they may be met with, so that he can examine them in detail should he so desire. It now only remains for us to notice the collections within the main building, which may be done in a brief sentence or two, inasmuch as they are mainly duplicates of the machines and implements exhibited in one or other of the localities outside the building which we have already noticed; or, being different in this respect, yet have little or nothing which calls for special notice here. In the French Department of the Great Machinery Gallery, the principal exhibitors are as follows;—MM. Pinet fils, of Avilly, Indre-et-Loire, who exhibit threshing machines, portable engines, horse gears, and a very well arranged and excellently well constructed water elevator by horse power. Next to this stand is that of Gerard Vierzin, who has a collection much the same in character as the preceding. On the wall opposite this is a collection of drawings of working men's cottages, and in a stand in the centre of the gallery a collection of specimens of Vicat's cements, bricks, tiles, &c.

In the Belgian Department there are various implements and machinery, the most noticeable of which are some flax machines.

The collection in the Dutch or Low Countries Department is very trifling, consisting of two threshing machines and one root-cutter, if we recollect aright. A very interesting collection of models of ploughs is to be met with in the Wirtemburg Department; they are arranged in cases on the wall, and have been all sold for the use of the Academy at Moscow; all the models have been made by Jas. Anselm. In the Austrian Department, a little further on, there is also a small but interesting collection of models, and of drawings of farm buildings, together with a few full-sized implements and machines. The Spanish Department show few, and the same may be said of the Indian Department, the most interesting features being a few ploughs. There are a few models in the Russian Department worthy of inspection; and, in conclusion, we would draw the attention of the visitor to the fine collection of drawings of farm buildings which are to be met with in the French and Belgian Departments.

INDEX.

Page
Agricultural Machinery at the Paris Exhibition, . . . 364
Air, Hot, Engine, Shaw's, . 287
Allan-Porter, the, Steam Engine, 216
American Machine Tools in the Paris Exhibition, . . 292
Anti-incrustator for Boilers, . 68

Baldwin's, Mr., Paper on Safety Valves, ... 77
Behren's Rotatory Engine, . 266
Belgian Tools, ... 299
Belts, Driving, the Care of, . 305
Bessemer Steel in Boiler Making, 53
Boiler, Action of the Anti-incrustator, ... 74—75
Boiler, Anti-incrustator for, . 68
Boiler Appliances at the Paris Exhibition, ... 96
Boiler at Paris, Manlell and Wibert's, ... 21
Boiler, Cast Iron Sphere, or Harrison's, ... 26
Boiler, Cornish, Application of Field Tubes to, ... 25
Boiler Explosions in the year 1866, 1
Boiler Explosions, Illustrations of, ... 113—148
Boiler Explosions, Prevention of, 162
Boiler Explosions, Mr. Martin's Report upon, ... 105
Boiler, Farçot, at Paris Exhibition, 20
Boiler, Feed Apparatus, . . 96
Boiler, Field's Safety, . . 21
Boiler Fittings, . . . 93
Boiler, Galloway's, . . . 16
Boiler, Gas Burning, . . 41
Boiler, Howard's, . . . 7
Boiler, Joints, Welded, . 51
Boiler, Lecherf's, at Paris Exhibition, ... 20
Boiler Making, . . . 52
Boiler Making, Bessemer Steel, 53
Boiler, Martin's, . . . 35
Boiler, points at which to supply Water to, ... 103

Page
Boiler, Schmaltz's, at Paris, . 19
Boiler Setting, Mid-feather Walls in, 58
Boilers, Foreign, at the Paris Exhibition, ... 19
Boilers, Gas-heated, . . 192
Boilers, Makers and Users of, . 4
Boilers, Marine, . . . 42
Boilers, Overheating, 150, 152, 156
Boilers in Paris Exhibition, . 6
Boilers, Rain Water in, . . 202
Boilers, Steam, Water, its effects on, 193

Carriages, Railway, . . . 337
Cast-Iron Sphere Boiler, or Harrison's, ... 26
Castings at the Paris Exhibition, 335
Cast Steel at the Paris Exhibition, 312
Coal, Effect of Exposure upon, 167
Coal at the Paris Exhibition, . 166
Coal Refuse, Utilization of, . 164
Coals, Steam, Monmouthshire, 170
Condensers, Steam, Hints to Inventors of, ... 246
Consuming Smoke, Apparatus for, 205
Corliss Steam Engine, . . . 233
Cornish Boilers, Application of Field Tubes to, ... 25
Cornish Boilers, Tubulous, as compared with, ... 39
Counterbalancing Reciprocating Engines, ... 250
Counterweights of Locomotives, Adjustment of, ... 276

Donkey Steam Pump, . . 101

Engine, Gas, Otto and Langen's, at the Paris Exhibition, . . 289
Engines, Locomotive, at the Paris Exhibition, . . 270—286
Engines, Reciprocating, Counterbalancing, ... 250
English Tools in the Paris Exhibition, ... 297
Equivalent, Mechanical, of Heat, 208
Expansion of Steam, . . . 261

INDEX.

Page
Agricultural Machinery at the Paris Exhibition, . . . 364
Air, Hot, Engine, Shaw's, . 287
Allan-Porter, the, Steam Engine, 216
American Machine Tools in the Paris Exhibition, . . 292
Anti-incrustator for Boilers, . 68

Baldwin's, Mr., Paper on Safety Valves, ... 77
Behren's Rotatory Engine, . 266
Belgian Tools, ... 299
Belts, Driving, the Care of, . 305
Bessemer Steel in Boiler Making, 53
Boiler, Action of the Anti-incrustator, ... 74—75
Boiler, Anti-incrustator for, . 68
Boiler Appliances at the Paris Exhibition, ... 96
Boiler at Paris, Manlell and Wibert's, ... 21
Boiler, Cast Iron Sphere, or Harrison's, ... 26
Boiler, Cornish, Application of Field Tubes to, ... 25
Boiler Explosions in the year 1866, 1
Boiler Explosions, Illustrations of, ... 113—148
Boiler Explosions, Prevention of, 162
Boiler Explosions, Mr. Martin's Report upon, ... 105
Boiler, Farçot, at Paris Exhibition, 20
Boiler, Feed Apparatus, . . 96
Boiler, Field's Safety, . . 21
Boiler Fittings, . . . 93
Boiler, Galloway's, . . . 16
Boiler, Gas Burning, . . 41
Boiler, Howard's, . . . 7
Boiler, Joints, Welded, . 51
Boiler, Lecherf's, at Paris Exhibition, ... 20
Boiler Making, ... 52
Boiler Making, Bessemer Steel, 53
Boiler, Martin's, ... 35
Boiler, points at which to supply Water to, ... 103

Page
Boiler, Schmaltz's, at Paris, . 19
Boiler Setting, Mid-feather Walls in, 58
Boilers, Foreign, at the Paris Exhibition, ... 19
Boilers, Gas-heated, . . . 192
Boilers, Makers and Users of, . 4
Boilers, Marine, ... 42
Boilers, Overheating, 150, 152, 156
Boilers in Paris Exhibition, . 6
Boilers, Rain Water in, . . 202
Boilers, Steam, Water, its effects on, 193

Carriages, Railway, . . . 337
Cast-Iron Sphere Boiler, or Harrison's, ... 26
Castings at the Paris Exhibition, 335
Cast Steel at the Paris Exhibition, 312
Coal, Effect of Exposure upon, 167
Coal at the Paris Exhibition, . 166
Coal Refuse, Utilization of, . 164
Coals, Steam, Monmouthshire, 170
Condensers, Steam, Hints to Inventors of, ... 246
Consuming Smoke, Apparatus for, 205
Corliss Steam Engine, . . . 233
Cornish Boilers, Application of Field Tubes to, ... 25
Cornish Boilers, Tubulous, as compared with, ... 39
Counterbalancing Reciprocating Engines, ... 250
Counterweights of Locomotives, Adjustment of, ... 276

Donkey Steam Pump, . . . 101

Engine, Gas, Otto and Langen's, at the Paris Exhibition, . . . 289
Engines, Locomotive, at the Paris Exhibition, . . . 270—286
Engines, Reciprocating, Counterbalancing, ... 250
English Tools in the Paris Exhibition, ... 297
Equivalent, Mechanical, of Heat, 208
Expansion of Steam, . . . 261

Page
Explosions, Boiler, in the year 1866, 1
Explosions, Boiler, and Illustrations of, ... 113—148
Explosions, Boiler, Mr. Martin's Report upon, . . . 105
Exposure of Coal, Effect upon, 167

Farçot's Boiler at Paris Exhibition, 20
Feed Apparatus for Boilers, . 96
Field's Patent Safety Boiler, . 21
Fittings of Boilers, ... 93
Foreign Boilers at the Paris Exhibition, ... 19
Foreign Machine Tools in the Paris Exhibition, ... 299
French Engines, Special Features of, ... 226
French Navy, Types of Ships in the, ... 353
French Steam Engines, Symmetry of, ... 230
Friction Wheels for driving Machinery, ... 308
Fuel, Liquid, ... 183
Fuel, Liquid, Pulverization of, 182
Fuel, Petroleum, as a Steam, . 176
Furnace, the Smokeless, . . 207

Galloway's Boiler, ... 16
Gas Burning Boiler, . . 41
Gas Engine, the Hugon, . . 291
Gas Engine, Otto and Langen's, at the Paris Exhibition, . . 289
Gas-heated Boiler, . . . 192
Gas as a Steam Generator, . 189
Gauges, Steam, ... 92

Hammer, Justice's "Dead Stroke," 297
Handles of Tools, . . . 306
Harrison, or Cast-Iron Sphere Boiler, ... 26
Heat, Mechanical, Equivalent of, 208
Hick's Engine at Paris Exhibition, 216
Hot Air Engine, Shaw's, at the Paris Exhibition, . . . 237
Howard's Boiler, . . . 7
Hugon Gas Engine, . . . 291

Illustrations of Boiler Explosions, ... 113—148
Iron, Cleveland, at the Paris Exhibition, ... 332
Iron and Steel in the Paris Exhibition, ... 319—326

Joints, Welded Boiler, [illegible]

Page
Lake's Smoke-Consuming Apparatus, ... 206
Lecherf's Boiler at Paris Exhibition, ... 20
Liquid Fuel, ... 183
Liquid Fuel, Pulverization of, . 182
Lock-nuts, ... 311
Locomotive, Adjustment of, Counter-weights, ... 276
Locomotive Engines at the Paris Exhibition, . . . 270—286
Lugne's Priming Preventer, . 104

Machine Tools in the Paris Exhibition, ... 292
Machine Tools, Foreign, in the Paris Exhibition, ... 299
Machinery, Agricultural, at the Paris Exhibition, . . . 364
Making, Boiler, ... 52
Manlell and Wibert's Boiler at Paris, ... 21
Marine Boilers, ... 42
Martin's, Mr., Report on Boiler Explosions, ... 105
Martin's Boiler, ... 35
Martin Process of making Steel, 330
Mid-Feather Walls in Boiler-Setting, ... 58

North German Tools, . . . 303
Nuts, Lock, ... 311

Oscillating Engine, Andrews', . 221
Overheating Boilers, 150—152—156

Page, Mr., on Railway Carriages, 337
Paris Exhibition, Boiler Appliances at the, ... 96
Paris Exhibition, Boilers in, . 6
Paris Exhibition, Coal at, . 166
Paris Exhibition, Foreign Boilers in, 19
Paris Exhibition, see various Papers upon at pp. 216, 364, 299, 292, 21, 20, 7, 335, 312, 289, 270, 286, 297, 332, 319, 326, 104, 101, 266, 268, 269, 224, 221.
Peat, Combustion, and Manufacture of, ... 174
Peat, Origin and Composition of, 171
Petroleum, What is it? . . 176
Petroleum for Locomotives, . 181
Petroleum as a Steam Fuel, . 176
Petroleum for Steamers, . . 178
Prendred, Mr. V., on Water-Tube Boilers, . . . 8, 16, 25, 39, 58

Page
Preventive of Boiler Explosions, 162
Priming Preventer, Lugne's, . 104
Propulsion, Hydraulic, . . 359
Prussian Tools, ... 302
Pulverization of Liquid Fuel, . 182
Pump, Donkey Steam, . . 101
Pumping and Winding Steam Engines, ... 235
Pumping Steam Engines for Town Water Supply, ... 237

Railway Carriages, ... 337
Railway Rolling Stock, English, an American View of, . . 348
Rain Water in Boilers, . . 202
Refuse of Coal, Utilization of, . 164
Riddel's Boiler-Feed Apparatus, 96
Rolling Stock of English Railways, an American View of, . . 348
Rotary Engine, Behren's, . 266
Rotary Engine, Pilliner and Hill's, 268
Rotary Steam Engines at the Paris Exhibition, ... 269
Rotary Steam Engine, Thomson's, 224

Safety-Valves, ... 77
Safety-Valves, Baldwin's Improved, 87
Safety-Valves, Remarks on, . 90
Schmaltz's Boiler at Paris Exhibition, ... 19
Ships, Types of, in the French Navy, ... 353
Ships of War, Halsted's, . . 357
Smoke-Consuming Apparatus, . 205
Smokeless Furnace, The, . . 207
Steam Boilers, Water, its Effects upon, ... 193
Steam Coals, Monmouthshire, . 170
Steam Engine, the Allan-Porter, 216
Steam Engine, Andrews' Oscillating, ... 221
Steam Engine, Hick's, at the Paris Exhibition, ... 216
Steam Engine, the Corliss, . 233
Steam Engine, Thomson's Rotatory, 224
Steam Engines, Special Features of French, ... 226
Steam Engines, Rotatory, at the Paris Exhibition, . . . 209
Steam Engines, Pumping, for Town Water Supply, . . . 237

Page
Steam Engines for Winding and Pumping, ... 235
Steam, Expansion of, . . 261
Steam Gauges, ... 92
Steam-Generator, Gas as a, . 189
Steam, Superheating, . . 258
Steel and Iron at the Paris Exhibition, ... 319—326
Steel, Cast, at the Paris Exhibition, 312
Steel, Martin's Process of, . 330
Steel, New Modes of Making, . 328
Superheating of Steam, . . 258
Swann's Safety-Valve, . . 88
Swiss Tools, ... 304

Tools, Belgian, ... 299
Tools, English, in the Paris Exhibition, ... 297
Tools, Handles of, ... 306
Tools, Machine, in the Paris Exhibition, ... 292
Tools, Machine, in the Paris Exhibition, American, ... 292
Tools, Machine, Foreign, in the Paris Exhibition, . . . 299
Tools, North German, . . 303
Tools, Prussian, ... 302
Tools, Swiss, ... 304
Tubes of Howard's Boiler, . 12
Tubulous as Compared with Cornish Boilers, ... 39

Utilization of Coal Refuse, . 164

Valves, Safety, ... 77
Valves, Safety, Remarks on, . 90
Valves, Safety, Swann's, . . 88

Water, its Effects on Steam Boilers, 193
Water Indicator for Boilers, Lemaillier-Pinel's Magnetic, . . 97
Water, Points at which to Supply, in Boilers, ... 103
Water, Rain, in Boilers, . . 202
Water-Tube Boilers, Mr. Prendred's Paper on, . . . 8, 16, 35, 39, 58
Welded Boiler Joints, . . . 50
Wheels, Friction, for driving machinery, ... 308
Winding and Pumping Steam Engines, ... 235

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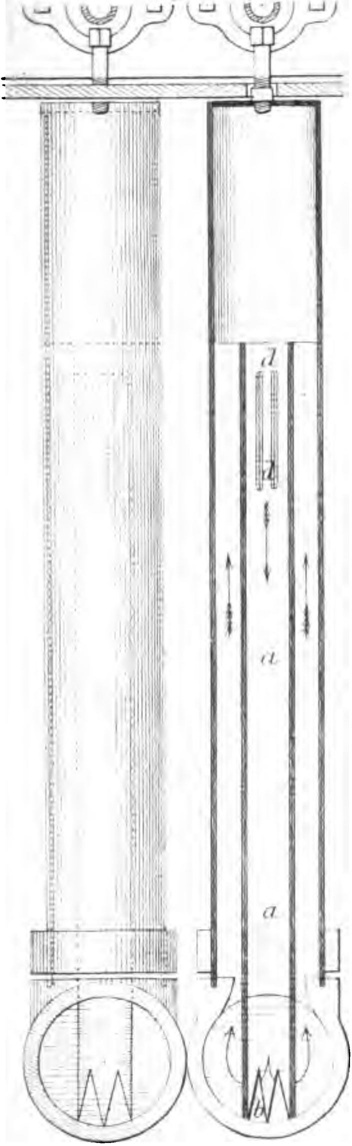

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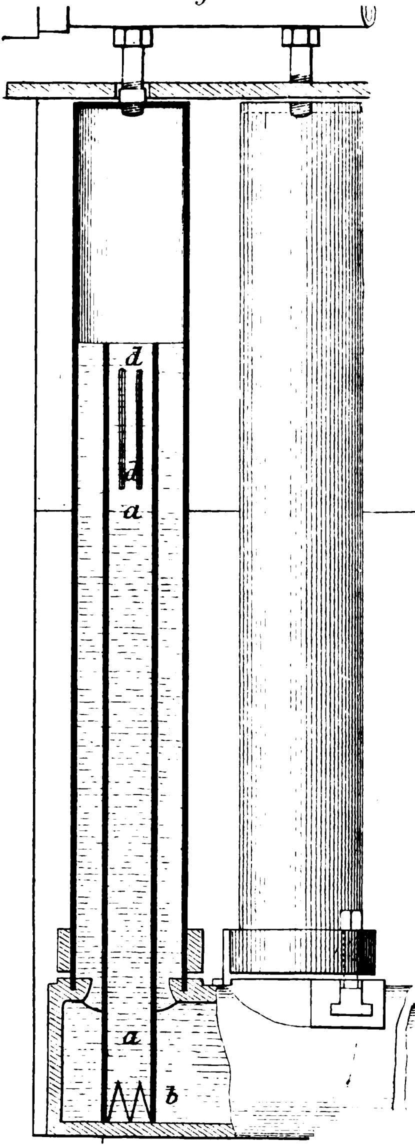

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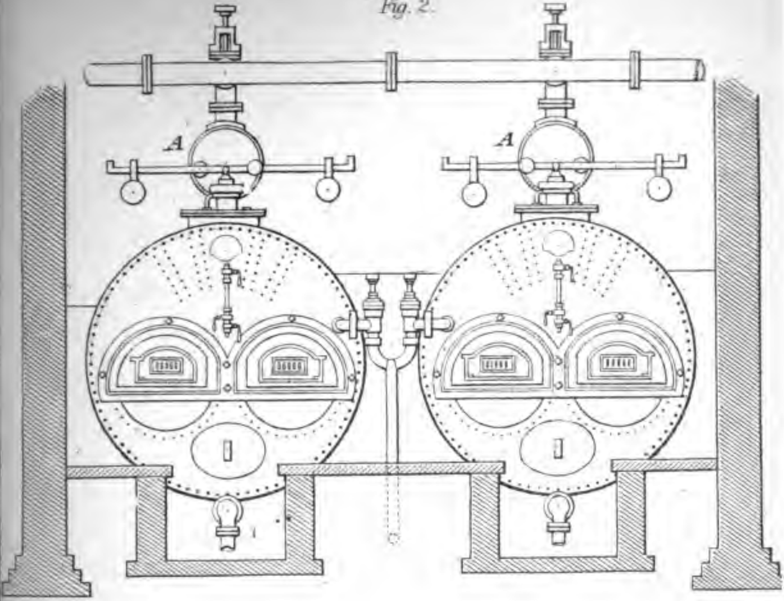

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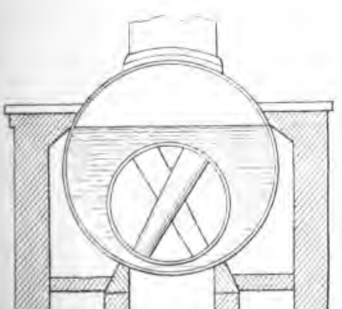

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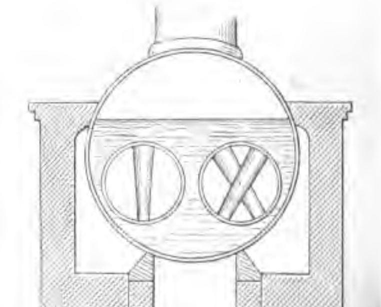

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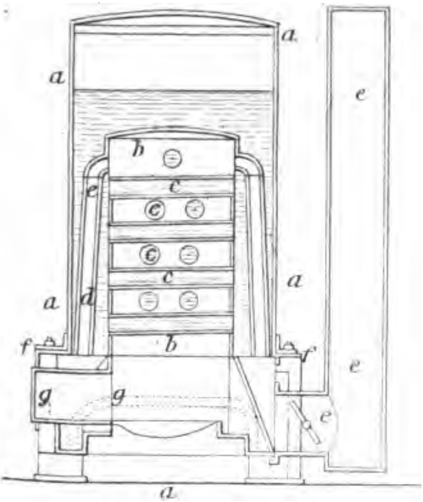

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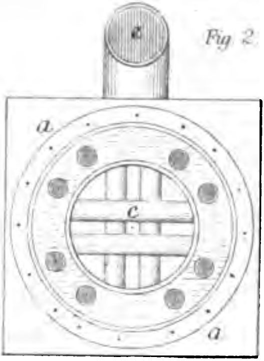

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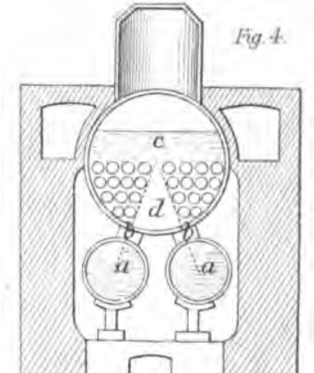

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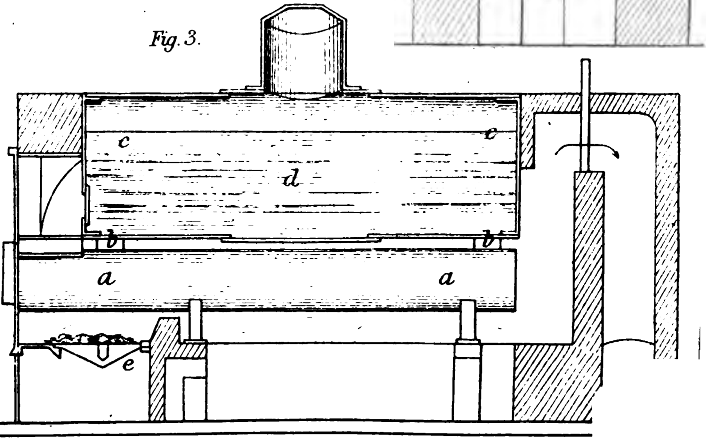

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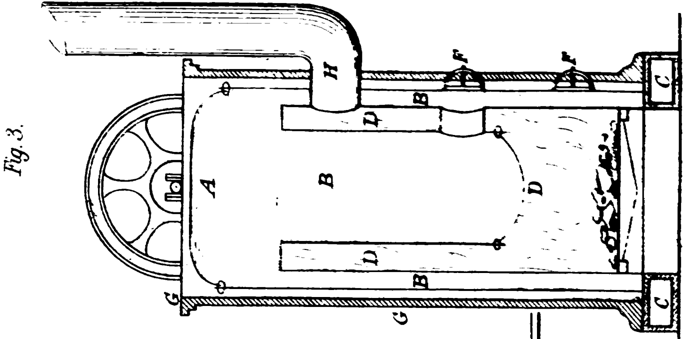

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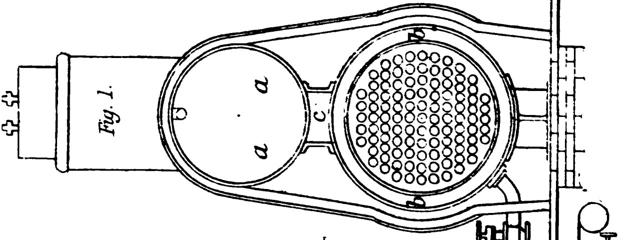

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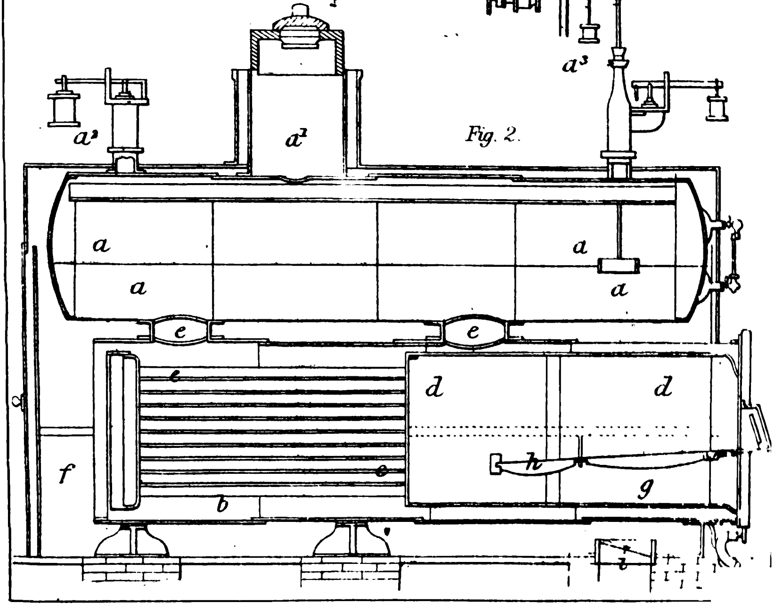

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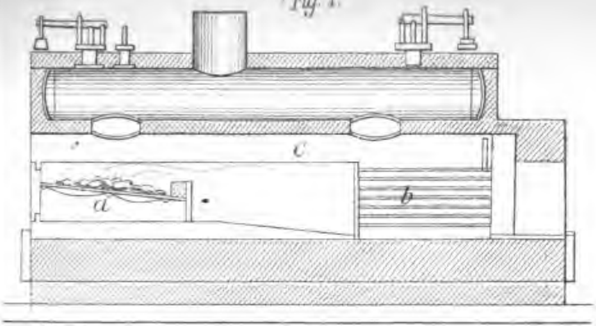

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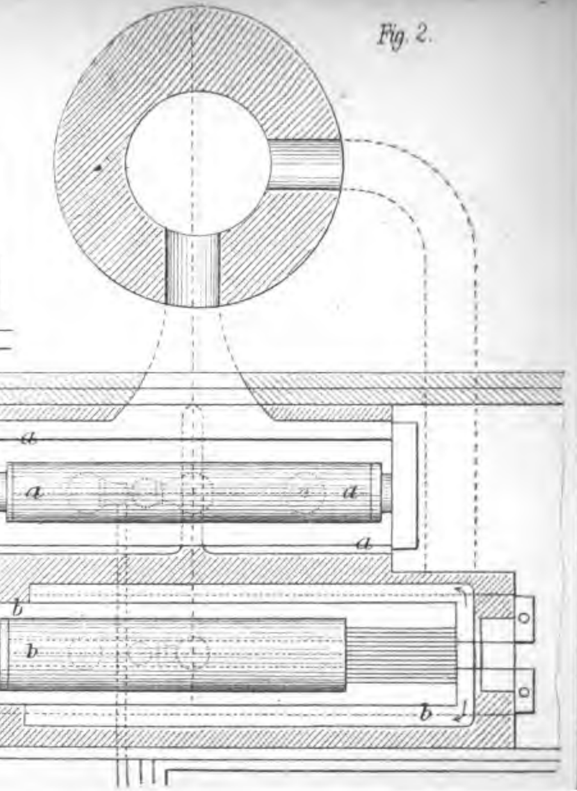

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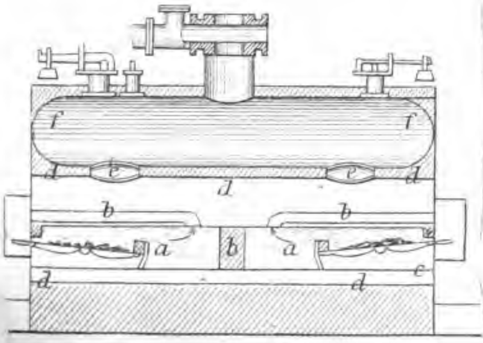

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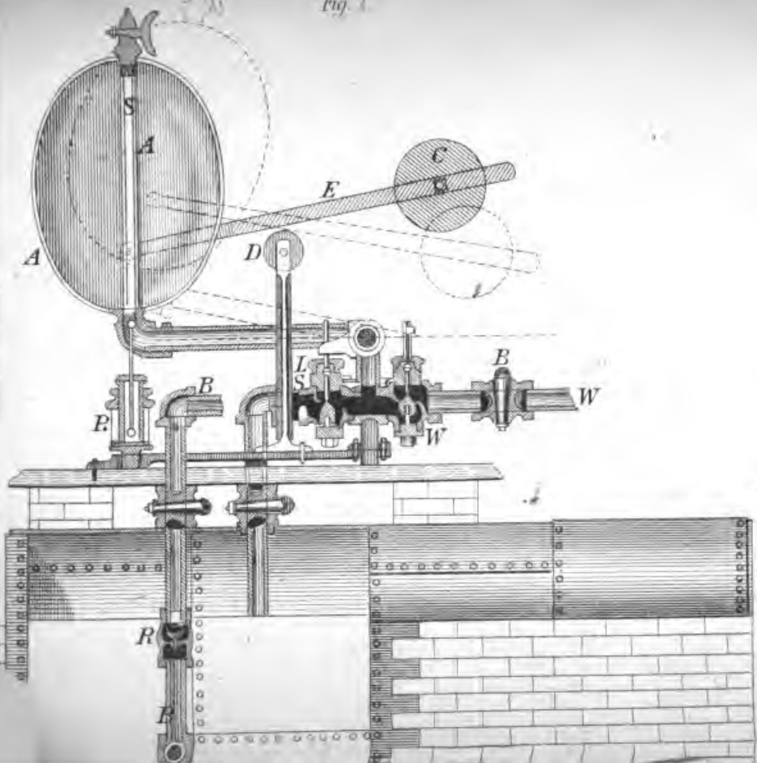

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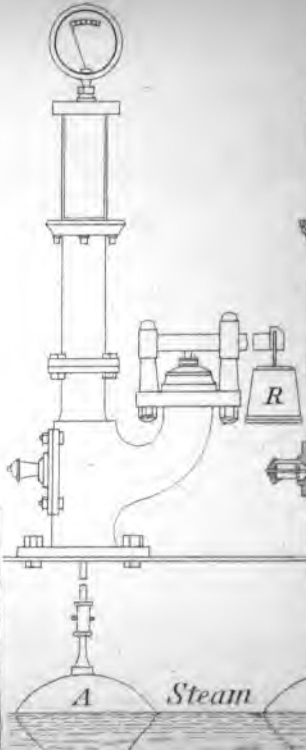

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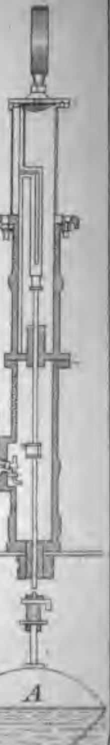

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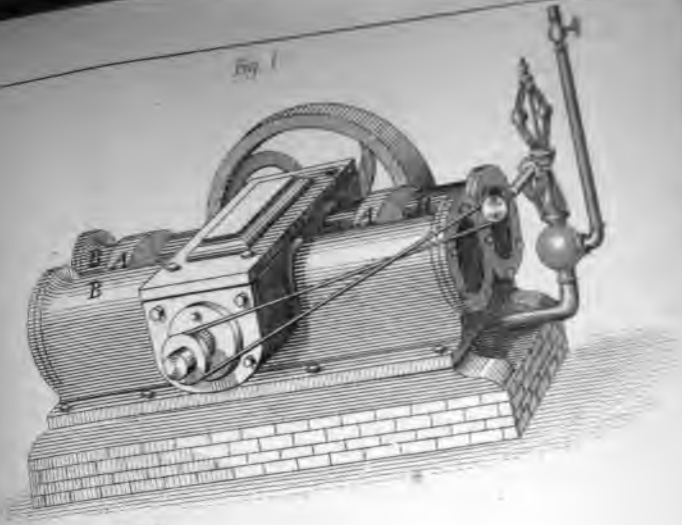

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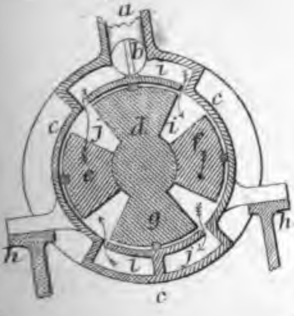

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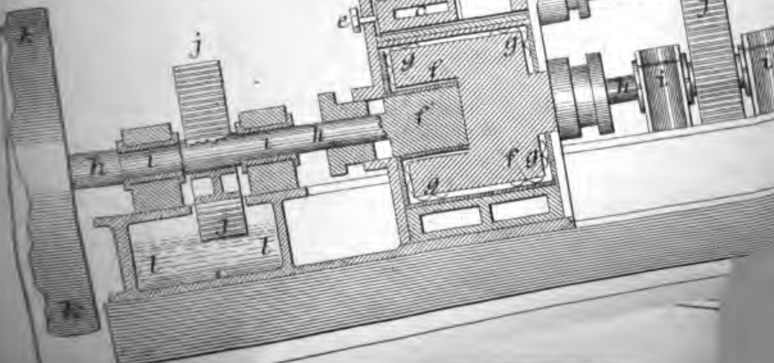

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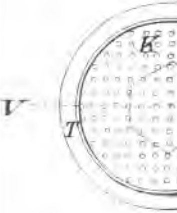

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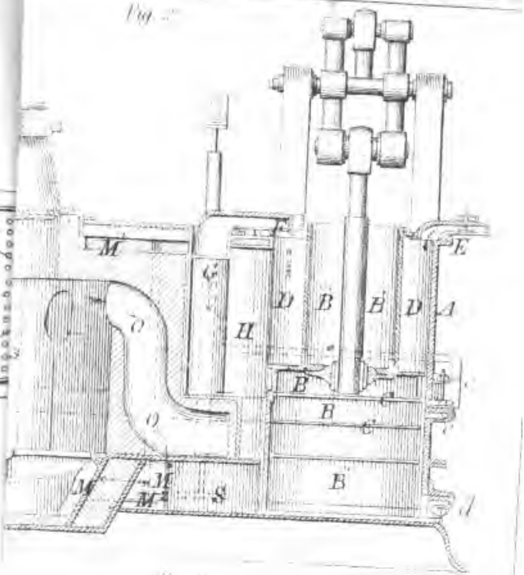

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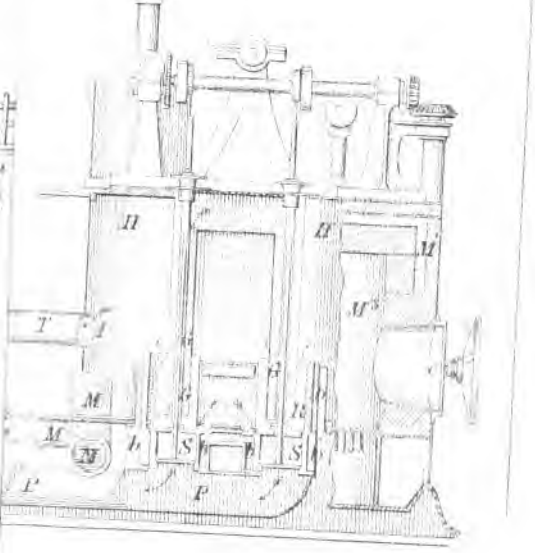

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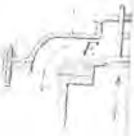

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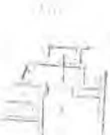

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